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CORROSION OF WATER MAINS

By H. R. Redington,[1] J. L. W. Birkinbine,[2] and F. N. Speller[1]

I. HISTORY OF STEEL PIPE

Production

The manufacture of steel pipe is an interesting subject. Many users, however, have never had the time, or the opportunity, to study its history, the processes of its manufacture, or the properties and characteristics of the metal from which it is made. The yearly production has reached well over four million tons. Pipe now represents from 8 to 9 percent of the total yearly iron and steel production, or about 11 percent of finished products, and may, therefore, be considered a major division of the steel business.

Underground lines

Somewhere in the United States at some time during 1929 some furnace made the billionth ton of iron and steel. Of this total, tubular products probably represented between 7 and 8 percent. That means that between 70 and 80 million tons of tubular products have been put into service in the last hundred years. About 75

[1] National Tube Company, Department of Metallurgy and Research, Pittsburgh, Pa.

[2] Consulting Engineer, Pittsburgh, Pa.

percent of this tonnage has been made and put into service in the last 20 years. Approximately half of this total tonnage has been used for water, oil, and gas lines. Most of these lines are buried underground. A recent survey of the oil and gas industry showed approximately 200,000 miles of iron and steel underground pipe lines. "Natural gas, oil, and gasoline lines constructed during 1930 totaled 20,731 miles at a total cost of $500,000,000. The estimated construction for 1931 to date totals 15,248 miles at an estimated expenditure of $533,000,000.[3] The total water lines now in service add considerably to this figure. Most of the water lines made from ferrous material are cast iron, wrought iron, or wrought steel. The steel pipe, in turn, is represented by such types as riveted, lap-weld, butt-weld, seamless, hammer-weld, electric-weld, spiral-weld, and lock-bar.

Early pipe

Pipe, while dating back to the use of the bamboo pole and hollow log for conveying water in tropical countries, and the pottery and lead tubes of the Egyptians and Romans, is, as we now think of it, a comparatively modern development. Iron, while known since 3400 B.C., did not come into general use until the fourteenth century. The displacement at that time of the direct extraction of wrought iron from ore by the indirect method of first carburizing the metal, thus turning it into cast iron, and when converting it into wrought iron by refining in the forge, gradually gave the product a constant and definite structure.

Wrought iron pipe

With the substitution of mineral coke from bituminous coal for vegetable charcoal, rapid developments were made in methods of refining, resulting in the introduction of the "Crucible Process" in 1740 and the "Puddling Process" in 1784. With the development of the "Puddling Process" the material used in the first welded pipe was called wrought iron, this being the only suitable material known at that time. Tubes were made by bending an iron plate or strip to form a "skelp" and the edges were welded together piece-meal by the smith hammering the red-hot metal over a rod or mandrel. In 1812 machinery was introduced for "welding and making barrels of firearms and other cylindrical articles."

[3] Pipe Line News, April, 1931.

At the same time Murdoch was perfecting his process of making coal gas for lighting purposes. Iron tubes, gas-tight, were essential. Old gun barrels were collected and screwed together into a continuous tube for conveying gas about the streets of London. The rapid extension of gas lighting developed a new necessity for iron tubes in quantity, which in turn required the production of tubes with greater facility.

In 1824, James Russell developed the first process of butt-welding. The importance of this process was the discovery that a sufficiently sound weld could be made by forcing at a welding heat, the butting edges of the tube against each other. This was followed in 1825 by the Cornelius Whitehouse process of butt-welding which is the basis of the present-day "bell process."

The introduction of the Whitehouse invention at once not only greatly reduced the price of iron tubes, but supplied a far superior article. In America, as in Europe, there was a fast-growing demand for better tubular products, due to the successful introduction of artificial gas for lighting purposes, the need for boiler tubes, an ever-increasing demand for durable tubes for water supply systems, and for industrial purposes. This necessitated the establishment of domestic industries for the manufacture of pipe, the first furnace being built in United States about 1830. Thus welded pipe, as we know it, is only 118 years old and has been manufactured successfully in the United States for 100 years.

Bessemer and open-hearth steel pipe

Steel pipe did not begin to replace puddled wrought iron until after the development of the Bessemer process in 1855 and the Open Hearth process in 1861. Even then there was some delay as, while these processes revolutionized the iron and steel industry and opened unlimited commercial and industrial possibilities, manufacturers were so engrossed in applying the new steel processes to rails, structural steels, etc., that its value for pipe making, on a commercial scale, was not immediately appreciated. It remained for Thomas J. Bray, Superintendent, Tube Department, Riverside Works, Wheeling, W. Va., to weld successfully the first steel pipe in 1887 as covered by his paper before the Engineers Society of Western Pennsylvania.[4]

[4] "The Manufacture of Welded Steel Tubing," January 17, 1888.

Present use

In 1890 less than five per cent of the wrought tubular products made in this country were steel. In 1930 approximately 96 per cent were made from Bessemer or Open Hearth steel. Great progress has been made in the last forty years. Today steel tubular goods reach into practically every commercial development. Steel pipe lines have well been called "The Arteries of Industry."

Pipe formed by riveting wrought iron sheets together was used for the conveyance of water in California in the early fifties. In 1868 a similar line was built for supplying water to San Francisco. One of the first lines of importance in the East was Conduit No. I for the City of Rochester, New York, which was laid in 1873–1875. There is some question as to the date of the first riveted steel water main laid in this country, but it is well known that the East Jersey Water Company built a steel water line to supply the City of Newark, New Jersey, in 1891. Electrically welded and the larger sizes of seamless are developments of the last few years.

Improvement in quality—specifications

Rigid specifications have been developed over a period of time covering the chemical and physical properties of the material from which the pipe is made, its fabrication, inspection, tests, joints, coatings, etc. Manufacturers have continually improved the quality of their finished product and have spent large sums of money in the modernization of manufacturing equipment, experimental work, and research. Steel as manufactured today is, therefore, of a higher quality than ever produced before and pipe is now available, in a wide range of sizes and various lengths, that has great physical strength with tensile strength running from 45 to 80 thousand pounds per square inch, sufficient ductility to take up all ordinary stresses and strains, with sound walls, high bursting and collapsing factors, smooth surfaces for application of various dips and coatings, and that is adaptable to various types of joints.

Fundamental cooperative research as regards quality of steel, such as that being done under the auspices of the Metallurgical Advisory Board composed of a large group of manufacturers in conjunction with the United States Bureau of Mines and Carnegie Institute of Technology, is a sign of the times. Various types of research work in the iron and steel industry are defined and classified and typical cooperative organizations for handling such problems both here and

abroad are described in a recent paper by one of the authors.[5] Specifications for pipe for large water mains are being contemplated by Sub-Committee 7-A on Steel Plate Pipe, of the American Water Works Association.

Interest in corrosion

While manufacturing processes are now well established and standard specifications cover the quality of material desired, the finished pipe is delivered to the customer and installed under service conditions over which neither the manufacturer of the plate nor the fabricator of the pipe has any control. Moreover iron has an inherent tendency to return to the combinations in which it is found in nature—in other words, it rusts. The action of these local factors, which are external to the metal itself, leads to the subject of proper installation and protection of material, which in turn leads to the general subject of corrosion in which both consumers and manufacturers are vitally interested.

II. CORROSION, THEORY, TYPES, CAUSES

Scope of problem

Generally speaking, corrosion is caused by the attack on metals by the media to which they are exposed, that is, atmosphere, moisture, vapors, fluids, acids, soil, etc.

The first stages form surface films with which we are all familiar because they change the color of the original article. If corrosion continues, the film or stain becomes a coating on the surface of the metal in the form of a loose powder or a more adherent, rather hard, scale. The discoloring of aluminum is caused by hydroxides, the coating thus formed acting as a protective film. Silver blackens; copper, brass, and bronze form vari-colored films.

Deterioration of metals has been taking place since man made the first metal articles, and has been gradually increasing through the ages with the increased use of metal, until today it is a world-wide problem. Under normal conditions all the common ferrous metals corrode when exposed to the elements, or are buried underground.

Steel, because more abundantly used, has often appeared to the layman to be more susceptible to corrosion than other materials. However, it is apparently a law of nature that when man takes iron

[5] "Cooperative Research in the Iron and Steel Industry," by F. N. Speller, American Iron and Steel Institute, May 22, 1931.

ore from the ground, heats and smelts it, and converts it into iron or steel, and places the finished articles in service, that is, exposes them to the elements, or buries them in the ground, nature slowly but surely converts it back into its original form. i.e., iron oxide, or rust. This process has been going on for so long and under so many conditions that nearly every one has taken it as a matter of course. Men build a fence of wire, a roof of sheets, etc., and when they have failed build new ones. To many it never occurred that it was often possible to prevent this loss, or waste, as it is now known, or at least delay replacement for longer periods of time, depending upon local service conditions. As time went on this prevention of loss, involving labor costs, loss of time, loss of production, and other factors, became an economic problem.

It was estimated a few years ago that at least 500,000,000 dollars are spent annually for the purchase of products to replace materials already in service, but which have failed due to corrosion. This amount represents only the first cost of the material, and is based on one to two per cent of that in use, namely, between 4 and 8 million tons. In many industries the cost of replacement is several times the cost of the material. The oil industry alone estimates an annual expenditure of one hundred million dollars for replacements.[6] When one stops to consider the ramifications of the production, distribution, refining, and marine divisions of the world-wide oil industry, the importance of prevention is at once apparent. American Petroleum Institute, the largest coöperating force engaged on the corrosion problem, has for some time recognized this as one of the major problems of the industry and has two main committees engaged in working out the best means of prevention. A more detailed review of the prorgess in prevention of corrosion in the oil industry was given at the Western Metal Congress meeting in San Francisco in February.[7]

That the corrosion problem is not a product of the age of steel is clearly evident by reference to the engineering literature of the early part of the past century. The deterioration of cast-iron water mains was causing concern in France in 1830 and extensive investigations were made leading up to the research work by Robert Mallet, 1838-

[6] American Petroleum Institute Bulletin, 9: 7, page 245, January 31, 1928.

[7] V. V. Kendall and F. N. Speller, "Progress in Prevention of Corrosion," Oil and Gas Journal, February, 1931; Metal Progress, February, 1931.

1843.[8] Thus tests have been going on for approximately one hundred years.

For many years interest in the subject of corrosion was more or less academic and confined mainly to theories and laboratory tests. A few engineers quickly realized its importance from a practical and economic standpoint and began to study the subject carefully as an engineering problem. Many things have been accomplished, but in looking back, it is now realized by a few of those most interested, that much time has been lost in arguments pro and con as to the application of various theories or the relative merits of different classes of material. This was not the fault of the theory, but due to lack of sufficient information by some who interpreted the theory. However, as many of the fundamental underlying causes are now fairly well understood, we have a much better understanding as to both the causes of corrosion under certain conditions and methods of prevention. Many of these methods have been carefully worked out and applied under practical, everyday operating conditions with satisfactory results. Naturally, with the increase in knowledge of the causes of corrosion, many "cure-alls" have been passed on to the public. Some, of course, are worthy of careful consideration and have considerable merit; others are worthless.

Cause or mechanism

In order that something may be understood about the fundamentals of ordinary corrosive action, it may be explained, briefly, that all metals, especially metals like iron and zinc, when placed in water and other media are subjected to a fixed tendency to go into solution. The rate of solution varies to a definite extent with each metal. The initial reaction is analogous to solution of material in acid, pure water being in effect a very weak acid. The acidity of the water determines the concentration of the hyrogen-ion in water, which in turn determines the initial speed of attack. As in all electrochemical reactions the initial speed of solution soon slows down, as the numerous electrochemical couples which form over the surface of the metal become "polarized" due to the accumulation of hydrogen in their cathodic surfaces. Ultimately the solution of the metal is stopped. In the case of iron and water a small amount of metal, less than 10 parts per million, is dissolved as ferrous hydrate which gives a pH

[8] Jour. N. E. Water Works Assn., 42: 3, pages 261–265.

of 9.6 and has a decided retarding action on further solution of the metal. Thus the first stage of corrosion of iron is not a serious matter if the reaction between the water and iron can be stopped at this point. In fact, this reaction cannot proceed unless the hydrogen film protecting the metal is removed in some way. This is usually brought about by means of something in the nature of a depolarizer, generally free oxygen, which also combines with the ferrous hydrate forming ferric oxide, commonly known as rust.

The second state of corrosion is thus caused by the oxidation of hydrogen and ferrous hydrate in solution by free oxygen from the atmosphere or in the water. Oxygen is soluble in water at normal temperature to the extent of about 10-parts by weight per million (seven cubic centimeters per liter). As water readily absorbs oxygen, when this element is used up, as in rusting under atmospheric conditions, or a fresh supply of oxygen is furnished with 4 to 8 cc. per liter of fresh water coming in contact with the material, it will be seen that the reaction will continue until the metal is destroyed or the reaction is brought to a stop through exhaustion of the available supply of oxygen. This is the reason why oxygen plays such an important part in determining the amount and character of corrosion under a given set of working conditions.

Types

For practical purposes, based on the different external conditions under which corrosion is known to occur, all corrosion has been divided into five main divisions, namely: (1) atmospheric, (2) underwater, (3) Underground, (4) chemical, (5) electrolytic.

CAUSES

1. *Atmospheric corrosion* (oxygen available in large excess). Atmospheric corrosion is characterized by the presence of oxygen in excess, moisture being present only part of the time. The metal is wetted and dried alternately and is subjected to the action of sunlight, heat, and variable weather. Nearly 80 per cent of the total steel and iron in use today is subject to this class of corrosion. The controlling variables are the proportion of the time the metal surface is wetted, the chemical content of the air in contact with the metal surface, and the composition of the metal.

2. *Underwater corrosion* (oxygen limited to the solubility of that gas in water). Underwater corrosion is characterized by conditions

almost the reverse of those in the atmosphere with respect to the ratio between the available supply of oxygen and water. The dissolved oxygen necessary for corrosion to continue is obtained originally from the air and is limited in amount. This type of corrosion applies to about ten per cent of all the ferrous metals in use today and includes water conduits, heating systems, steam boilers, etc. The controlling factors are oxygen concentration, hydrogen-ion concentration, composition of the water, rate of motion, temperature, and protective scale or coatings.

3. *Underground corrosion* (oxygen depending upon moisture present and other factors). Underground corrosion is characterized by the fact that it combines some of the factors of atmospheric corrosion, of underwater corrosion, and of chemical corrosion, together with some factors peculiar to itself. It is further characterized by marked pitting due to the effect of dissimilar soils or varying composition of soil, water, and other localizing factors. The amount of dissolved oxygen available depends upon the water content of the soil and varies with the structure and composition of the soil, the distance below the surface, the rate of diffusion of air, and the rate of flow of the soil water. The electrical conductivity of the soil water is also an important factor and is influenced by the concentration of salts present in solution. Over half the annual pipe tonnage is used underground.

4. *Chemical corrosion.* Chemical corrosion is characterized by the action of various chemical solutions and vapors, various acids, salts, and bases, and other solutions used in the chemical industry.

5. *Electrolytic Corrosion* (electrolysis). Electrolysis is a form of corrosion due to stray electric currents and is the result of electric currents of external origin leaving the metal. It is usually characterized by severe localized pitting. Briefly, it may be described as the process whereby an electric current originating outside the metal and passing from an electrode to an electrolyte causes solution of the metal. It also includes many chemical changes at the surface of an electrode, resulting from the chemical changes in the electrolyte. This action is independent of the heating effect of the electric current.

III. CORROSION PREVENTION

Corrosion prevention has been given much study both here and abroad as corrosion is now recognized as a world-wide engineering problem. As a result preventive measures are being studied by

both purchaser and manufacturer. Being an economic problem, the practical solution is based, to a large extent, on the cost of prevention as compared with the cost of direct or indirect replacements.

Progress is being made in the study of protective films and their practical value. The retardation of corrosion is sometimes brought about in nature by the formation of protective films. These films start to form shortly after the metal comes in contact with the corroding agent; they consist essentially of the products of corrosion and attain their maximum protective power after a certain period of time. This may be called a self-healing property possessed by certain metals without which they would corrode at a higher rate and, therefore, be less useful. The value of developing this important property of metals has been appreciated for some time.[9] Recent work on the fundamental processes of corrosion has involved a close study of metal surface films and potentials and indicates that the formation or lack of formation of protective films on the surface of the metal is an outstanding factor as regards its ability to retard corrosion.

Passivity has also been satisfactorily connected with the formation of primary stable oxide films. Improvement in methods of making potential measurements has permitted the determination of the course of the potential curve with time. The results of such measurements correspond to the formation of films—a rising potential indicating that weak points are being repaired, a falling potential that breakdown is extending. Thus a high final potential indicates immunity from attack; a middle value, slight rusting; and a low value, profuse rusting.

The increased resistance to corrosion of chrome steels in the polished condition is well known. Chromium has the power of forming a very resisting invisible film in oxidizing media, but in non-oxidizing acids such as hydrochloric or sulphuric, where such films cannot exist, it dissolves even more rapidly than pure iron.[10] Surface films, therefore, can either inhibit or accelerate corrosion, depending upon their physical and chemical properties and continuity. Discontinuous films are the main cause of pitting. Thus the artificial production

[9] Speller, F. N., "Film Protection as a Factor in Corrosion," Am. Electrochem. Soc., 46, 1924; and Speller, F. N., "Surface Films Protect Metals Against Corrosion," Chem. & Met. Eng., 36; 2, February, 1929.

[10] Forrest, H. O., Roetheli, B. E., and Brown, R. H., "The Initial Corrosion Rate of Steels," Ind. Eng. Chem., 22, p. 1197, 1930.

of dense tightly-adhering or continuously produced self-repairing films are a possible means of solving many corrosion problems. The use of sodium silicate and dichromate in refrigerating systems is a well-known example.

Preventive measures

1. *Atmospheric corrosion* (*prevention*). Under atmospheric conditions the film-forming ability of the metal is very important. The greater resistance of copper steel to atmospheric corrosive influences is well established. Results of many tests including the very comprehensive tests conducted by the American Society for Testing Materials[11] at Annapolis (sea atmosphere), Pittsburgh (industrial atmosphere), and Fort Sheridan (rural atmosphere) indicate that the life of steel exposed to atmospheric corrosion has been increased from two to five times by the addition of small amounts of pure copper. This increased resistance of copper steel seems to be due to a re-precipitation of a copper film on the surface of the steel. The enrichment of the surface film in copper corresponds with the decrease in rate of corrosion.

The development of chrome and chrome-nickel steels and other stainless steel alloys indicates the trend toward the improvement of the basic materials. However, special metallic coatings for protection against the elements have also been given special attention and their practical application has been quickly appreciated. Zinc, zinc alloys, cadmium, and chromium electro-deposited coatings have been successfully adapted by industry to specific purposes. The use of chromium for plating automobile radiator shells quickly made the public "plating conscious." The result was that the manufacturers had to solve promptly many plating problems by a large amount of scientific research.

2. *Underwater corrosion* (*prevention*). Water engineers now recognize that water-supplies require treatment to prevent corrosion as well as for hygienic reasons. Methods of analyses and expression of results are, however, not yet standardized. A movement is now on foot[12] to develop and standardize the methods of analyses of water for domestic and industrial uses. The mode of expression and in-

[11] Yearly reports of Committee III of Committee A-5, A. S. T M.

[12] A. S. T. M. Committee on Water Analyses.

terpretation of results should also be defined with respect to corrosion and scale formation.[13]

Water-supplies in many localities are becoming more corrosive due to pollution, chemical treatment, and filtration. Such treatment often reduces the ability of the water to form and lay down protective coatings on the inside of pipe. As water treatment is necessary and desirable and is constantly being extended, measures should be adopted now in order to prevent serious damage from interior corrosion in the future. This problem is becoming better understood and economical means are being applied in many cases by industrial water chemists. Lime and soda ash are being successfully used for industrial purposes, the amount depending upon the soluble inorganic material with which these reagents interact.

Corrosion of boiler tubes, steam supply lines, return lines, and hot water piping in low, medium and high-pressure stationary plants, locomotives, and marine work is now being kept under control by deaeration and water conditioning. Deaeration is an established method for reducing free oxygen and corrosion. Boiler water free from oxygen attacks steel only slightly.[14] An article by R. E. Coughlan in the *Railway Age* of October 25, 1930, "Boiler Tube Corrosion Halted by Hot Process Treatment" indicates that the favorable performance of a 25,000 gallon per hour hot-process lime soda ash and sodium aluminate softener equipped with a deaerator and a battery of quartz filters installed April, 1928, in the Chicago Shop Power House of the Chicago and North Western Railroad has proved the value of this treatment for railway water-supplies.

The paper by C. R. Knowles,[15] Superintendent of Water Service, Illinois Central System, Chicago presented at the 1930 St. Louis

[13] D. S. McKinney, "Interpretation of Water Analysis," Ind. and Eng. Chem. Analytical Edition, 3, page 192, April 15, 1931.

Norman J. Howard, "Water Analysis and Water Purification," The Canadian Engineer, March 17, 1931.

[14] Speller, F. N., "The Corrosion Problem in Connection with Water Works Engineering," Jour. New Eng. Water Works Assn., 39: 1, 1925; also, "The Problem of Steam Boiler Corrosion," J. Am. Water Works Assn., 16: 6, July, 1926; also, "Treatment of Boiler Feed Water," The Fuel Economist, 4, 441, 1929.

Abstract Sub-Committee IX, Joint Research Committee on Boiler Feed Water Studies; Also, American Society of Mechanical Engineers Report No. 21—Bibliography.

[15] Knowles, C. R., "The Development of Railway Water Supply Practice," JOURNAL A. W. W., 23, p. 481, April, 1931.

Convention with J. B. Wesley, Engineer of Water Service, Missouri Pacific Railroad, St. Louis, and C. H. Koyl, Engineer of Water Service, Chicago, Milwaukee, St. Paul and Pacific Railroad, Chicago, gives an indication of the far-reaching practical results to be obtained from studies of this kind.

Corrosion in refrigerating equipment and circulating water systems has been brought under control by the use of film-forming inhibitors such as sodium silicate and dichromate. Definite recommendations were the result of the work of the Corrosion Committee of the American Society of Refrigerating Engineers.[16] Where condensers are exposed to alternate wetting and drying, copper steel pipe has proved of advantage. The smooth scale free surface of cold-drawn seamless tubing seems to be of some advantage for absorbers.

Oil refinery corrosion is gradually being overcome by the development of new corrosion-resisting alloy steels, such as chrome and chrome nickel steels, also through chemical treatment of the crude oil and by the use of protective linings.

For certain corrosive domestic, saline, and mine waters, an interior lining of cement has proved effective. Cement-lined pipe has been known for approximately one hundred years. An investigation of pipe corrosion made in 1836 by the French Academy of Science led to a favorable report as to its effectiveness in preventing oxidation and the formation of tubercles. Incidentally it will be noted that cement lining of water mains, which has been rather widely advocated in recent years, was first suggested and used for the protection of cast-iron mains almost a hundred years ago.

In America, experience with cement-lined pipe covers a period of about ninety years. In 1843 a machine for lining pipe with cement was patented by Jonathan Ball. The oldest underground installations in use at the present time are in the New England States and are apparently in good condition after 40 to 60 years of service. Larger cement-lined pipe, known as Phipps Patent Pipe, was used in various Eastern and Southern cities in the years following the Civil War. This pipe was a thin (about $\frac{1}{16}$ inch) shell of sheet iron riveted into a pipe and covered outside and inside with $\frac{1}{2}$ to $\frac{3}{4}$ inch of cement. The outer cement covering was in turn protected by a second iron shell. This pipe was in service from 1890 to 1926 in

[16] Report of Corrosion Committee, The American Society of Refrigerating Engineers Journal, July, 1928.

Greenville, South Carolina. Similar pipe has been in service since 1880 in the suburbs of Philadelphia.

Experience with highly tuberculating water indicates that cleaning of water mains is required, and that results are not entirely satisfactory as formation apparently develops more rapidly after each operation. A series of tests made by J. E. Gibson, Manager and Engineer, Water Department, Charleston, S. C., shows that cement-lined pipe prevents tuberculation. Cement-lined pipe also reduces friction. The Water Works Practice[17] states that, "In most locations concrete and cement-lined pipes suffer less impairment in carrying capacity than do metal pipes."

A special low-soluble aggregate mixture has recently been developed that seems to hold interesting possibilities.[18] Pipe lined with this corrosion-resisting cement is now available. Mixtures of this type, approximately a half-inch thick, are also being used successfully in the protection of the inside of industrial hot water tanks. In order to protect the interior of pipe in buildings, without removal, means have also been developed to recondition pipe while in place.[19] The rust and carbonate scale accumulations are first removed with compressed air and an abrasive and a lining of thin special cement applied under pressure.

3. *Underground corrosion* (*prevention*). The corrosion of metal buried in the ground is generally referred to as soil corrosion. The action is attributed to the characteristics of the soil. This local action does not include the effects from stray electric current. There are, of course, many general divisions of soils but each type is usually limited to certain sections. The action of any given soil on pipe depends to a large extent on the rainfall, temperature, depth of burial, type of trench, drainage, back filling, and the way in which the earth has been tamped around the metal.

The electrolytic theory of corrosion, which accounts for differences in the corrodibility of different materials, also clearly points out the factors external to the metal, differences in contacts between the soil and pipe, different soils in contact with the same pipe, etc., and definitely illustrates that corrosion cannot be eliminated by simply

[17] Manual of the American Water Works Association, 1925, page 291.

[18] Chappell, E. L., "Chemical Characteristics of Cement Pipe Linings," Ind. & Eng. Chem., 22, page 1203, November, 1930.

[19] Chappell, E. L., "Cleaning Rust from Water Pipes," Domestic Engineering, November 2, 1929.

using a purer metal. Further, it has been definitely determined that a metal most suitable for one type of service, for instance, atmospheric, is not necessarily best suited for underground, or underwater service.

As approximately fifty per cent of the total steel pipe and tube production of the country is used for oil, gas, and water lines, and other underground purposes, naturally with this tremendous tonnage subjected to these underground influences external to the metal, the subject of soil corrosion has been of vital interest to both manufacturers and consumers. Results of years of experience and hundreds of tests indicate that no one class of ferrous materials is superior to others under all soil conditions and that the study of soil corrosion is a very complicated subject. The factors governing soil corrosion are so many and so complex that an adequate study of the subject is almost beyond the facilities of a single company or laboratory. It would appear to be an ideal problem for cooperative effort. In the last few years much has been done along this line.

There are many sections throughout the country where soil corrosion is not a problem. There are any number of old oil, gas, and water lines which indicate that the life of unprotected steel pipe in certain soils will be from 75 to 100 years or more. On the other hand, there are certain sections where soil corrosion is a problem of prime importance; the life of unprotected material in these localities is comparatively short. There are also many localities throughout the country where the action of the soil will limit the life of pipe to some period between these two extremes. Therefore, since soils show a considerable variation in corrosiveness, ranging from well-drained gravel and certain kinds of clay, which give very little trouble, to alkali and acid soils in which pipe often fails in a few years' time, it is not surprising that the rate of corrosion of a particular material in a particular locality will depend to a large extent upon local soil conditions.

This holds true for cast iron and wrought iron, as well as for wrought steel. In some kinds of soil, cast iron is subject to a peculiar form of disintegration known as "graphitization." Cast iron carries about five and one-half per cent of foreign material. When the metallic iron is removed by corrosion, some of this material remains, forming a structure having some strength, and of the form of the original casting, but which can easily be cut with a knife. This may be strong enough to carry water or gas under low pressure if

left undisturbed. In an article, "Self-Corrosion of Cast Iron and Other Metals in Alkaline Soils"[20] results are given of extensive investigations of corrosion of cast-iron pipe in Winnipeg and other Canadian Northwest cities where this kind of soil corrosion is prevalent. The soils which have been found to attack cast iron most actively in this way carry a large per cent of soluble salts, of which the sulphates of lime and magnesium predominate. The water content which gives the highest soil conductivity seems to produce the most rapid corrosion.

Among water works engineers it is generally agreed that the life of steel pipe has been considerably underestimated. As early as 1900, Mr. John R. Freeman, Past President, American Society of Civil Engineers, stated that, "The reliability, utility, and economy of properly constructed large steel conduits was established," and estimated, after careful observation, a life of over 50 years for steel penstocks.

Metcalf and Eddy, in their book, "Design of Sewers," 1914, state that their examination of the 47 year old Spring Valley Water Company line in California indicated that "steel pipe can be expected to carry its pressure for a period of 60 to 75 years."

Mr. John Swan, Director of Department of Public Works, Pittsburgh, and Managing Engineer, Charles A. Finley, stated in 1919 that a section of 60-inch steel line laid in 1895 was practically in perfect condition.

Mr. J. Waldo Smith, in 1920, estimated the life of steel pipe as more than 50 years.

Mr. Allan Hazen, in commenting on the investigation of the electrolysis of the steel water main in Akron, Ohio, in 1922 stated, "I am sure that a careful examination of the oldest steel pipe lines in water works service would indicate a percentage of depreciation much lower than any one would have thought probable when these lines were laid."

Mr. T. A. Leisen, in 1923, in a paper on "Steel Pipe for Large Water Mains" refers to experiences with several steel water mains after long service and points out that apparently steel mains may attain a useful life of 100 years in some localities.

At a discussion of this question during the American Water Works

[20] W. Nelson Smith, Electrical Engineer of Winnipeg, Canada, and Prof. J. W. Shipley, University of Manitoba, Canada, J. Eng. Inst. of Canada, 4–10, 1921.

Association meeting in New York May, 1924, following D. H. Maury's paper "Large Supply Mains" the concensus of opinion was that the life of steel pipe was much longer than had been anticipated and that, due to the great advance in the knowledge of protective measures and means for permanently repairing leaks by the welding process, and the actual life of steel could not be predicted. It was admitted that some steel mains have been in use with no apparent damage for 50 years and that with proper protection the ultimate life could be greatly extended. Mr. Maury estimated the life of steel pipe to be "from 40 to 80 years."

The Water Works Practice Manuel of American Water Works Association, 1925, page 290, states that the use of steel pipe as a water-carrying medium dates back approximately 45 years.

The 1925 report of the North Jersey District Water Supply Commission, Page 74, states that, "Several recent inspections of the interior of the pipe have shown that they are in a satisfactory condition considering their long use and may reasonably be expected to continue in service for many years." The Pequannock line of the City of Newark has been in continuous service for 37 years without requiring major repairs, the Boonton-Jersey City line 30 years, and the Little Falls-Belleville line 31 years.

Mr. Lochridge, Springfield, Mass., Water Department, states that a 42-inch steel line after 21 years of service is in very good condition and that the line shows 20 percent greater carrying capacity than originally anticipated for time in service.

The United Gas Improvement Company, Philadelphia, has kept detailed records of iron and steel gas service pipe installations since 1898 which indicate that the life of these smaller sizes of steel would be approximately 45 to 50 years.

Mr. Joseph F. Putnam[21] states that, "We frequently hear the statement that the pipe made at present is inferior to that of 'the good old days.' Many old-time pipe liners tell us that the pipe laid years ago was much better than the pipe of today. It lasted longer, and there was less trouble from corrosion. While the latter statement itself is partially true, the deduction usually made is false. The pipe of today is as good as, or possibly better, than that of yesterday from the corrosion-resisting standpoint; but it is, nevertheless, true that shorter life and more corrosion trouble is frequently found

[21] "Soil Corrosion Causes and Predetermination," Eleventh Annual Meeting, American Petroleum Institute, Chicago, Ill., November 13, 1930.

on recent pipe lines. There are at least five reasons for this: Location, stray current, paralleling of lines, increased moisture content of soil, and difference in level. In other words, most corrosion is caused by the environment rather than by metallurgical differences in pipe."

While under exceptionally unfavorable service conditions the 30-inch three-hundred-mile Coolgardie, Australia, main installed in 1900 has given some trouble (the water supply being high in chlorides of sodium and magnesium while pipe was buried in sandy soil impregnated with salt), it is well known by those best informed, and as shown in a recent paper by Major F. Johnstone-Taylor,[22] that the local engineers have determined after twenty-five years' experience and practical tests that steel pipe is best suited for their needs. All the leading cities throughout Australasia such as Melbourne, Sydney, Adelaide, Perth, Brisbane, Auckland, Wellington, and others are using steel water mains with satisfactory results. The original Melbourne main, laid in 1884, was recently reported as being in "as good preservation as when laid."

Probably the best evidence of the successful application of steel pipe for water mains is the rapidly increasing demand from all parts of the world.

Even in what is now looked upon as very bad soil conditions, the records of replacements of some of the old iron and steel transcontinental oil lines show an average annual replacement of only 0.35 of one percent of the lines over a period of thirty years. The largest portion of these replacements occurred in the latter half of the period and on bottom of pipe. As these lines are now being repaired by welding the pits, half turning the pipe in the ditch so that the former bottom-pitted sections are on top, and the whole thoroughly recoated, the additional life of the pipe will extend over a period of many years. In many parts of the country cases are known where oil and gas lines show practically no corrosion in that length of time.

In bad soil conditions it is either necessary to remove the cause or protect the material. As it is impracticable to remove the cause, most pipe buried in bad soil conditions is coated. As the factors external to the metal are far more important in controlling the rate of corrosion than the chemical properties of the material, the life of the material under these conditions is, therefore, in direct propor-

[22] "Some Notes on Performance of a Large Steel Water Main," Water Works Engineering, January 14, 1931, pages 49 and 50.

tion to the precautions taken. As far as we know, it has been the practice in the past, and is the practice at the present time, to use protective coatings on water mains.

The Bureau of Standards Soil Corrosion tests[23] are the most extensive series of comparative soil corrosion tests attempted to date. The object is to determine the extent of and the factors influencing the corrosive action of the various classes of soil, the differences in the corrosion rate of various metals, and the effectiveness of certain types of protective coatings. The Bureau now has eleven men, including three research associates, working on the various phases of this problem. Over sixteen thousand specimens are involved. Forty-seven soils were selected and sufficient specimens of each kind of

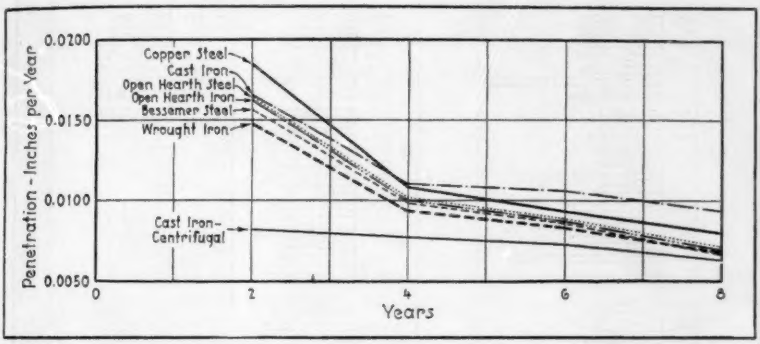

FIG. 1. BUREAU OF STANDARDS SOIL CORROSION INVESTIGATION. WEIGHTED AVERAGE OF MAXIMUM PITS FOR EACH MATERIAL IN ALL SOILS

material buried to permit the removal of a complete set every two years up to and including ten years. The test was started in 1922. To date the two, four, six, and eight-year specimens have been removed. The Bureau of Standards has drawn no definite conclusions. Coöperating manufacturers inspect the samples, attend the conferences in Washington, at which time the progress reports are rendered, and are privileged to draw their own conclusions. After the last inspection thirty-two papers were presented and discussed at the Bureau's meeting in November, 1930, covering the interpretation of soil-corrosion data, the correlation of soil characteristics with corrosion, the effects of earth currents on pipe lines, the testing of soils,

[23] Bureau of Standards Research Paper No. 95, "Soil-Corrosion Studies 1927-28."

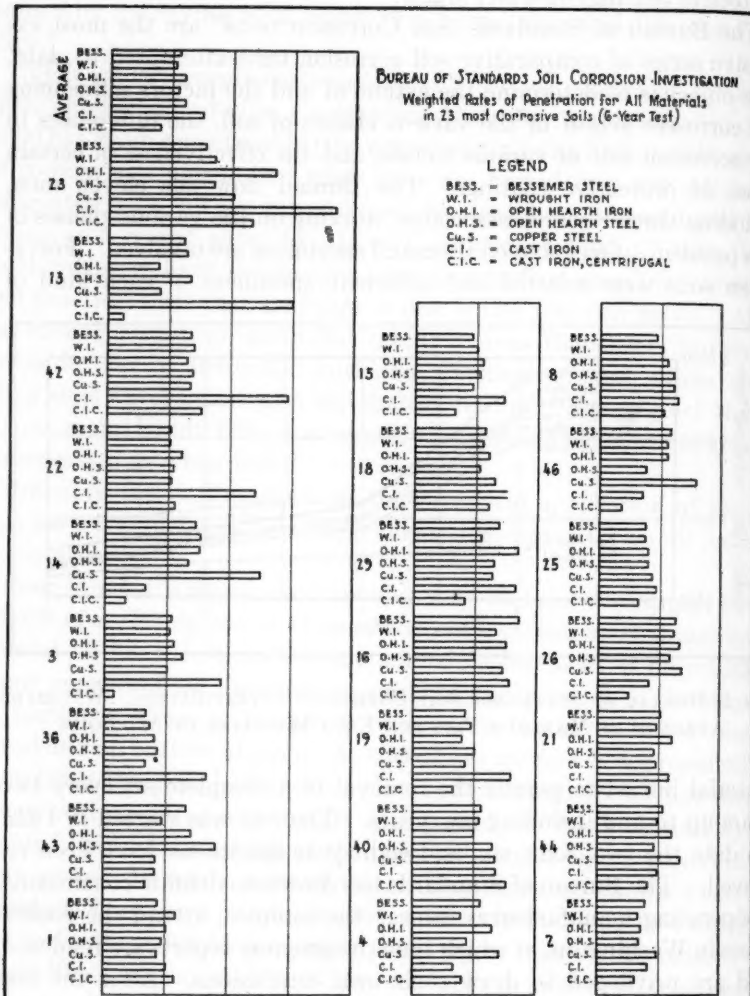

Fig. 2

(See page 1669 for explanation)

primers, and pipe line coatings. Figures 1 and 2, prepared by V. V. Kendall, Department of Metallurgy and Research, National Tube Company, give a view of the results obtained in all soils (8 years) as compared with the results obtained in the twenty-three most corrosive soils (6 years). There is practically no difference in the average result, although individual rates vary with the different soils. No one material is immune under all conditions or is better in all soils. It is also interesting to note that this test proves that wide variations in shape and depth of pitting are associated with variations in soil characteristics, and that in the same soil open-hearth iron, open-hearth steel, wrought iron, bessemar steel, and copper steel all show practically the same depth of pitting. Results also indicate that the rate of penetration decreases with time and that a straight line depreciation curve should not be used for the determination of the life of an underground pipe system. Briefly, the whole test may be summed up by a statement from one of the Bureau's reports to the

Explanation of Figure 2

NUMBER	SOIL	PLACE	TIME BURIED
			years
23	Merced Silt Loam	Buttonwillow, Calif.	6.16
13	Hanford Very Fine Sandy Loam	Bakersfield, Calif.	5.89
42	Susquehanna Clay	Meridian, Miss.	5.97
22	Memphis Silt Loam	Memphis, Tenn.	5.55
14	Hempstead Silt Loam	St. Paul, Minn.	5.83
3	Cecil Clay Loam	Atlanta, Ga.	6.04
36	Ruston Sandy Loam	Meridian, Miss.	5.97
43	Tidal Marsh	Elizabeth, N. J.	6.16
1	Allis Silt Loam	Cleveland, Ohio	5.50
15	Houston Black Clay	San Antonio, Tex.	5.93
18	Knox Silt Loam	Omaha, Nebr.	5.78
29	Muck	New Orleans, La.	5.99
16	Kalmia Fine Sandy Loam	Mobile, Ala.	5.97
19	Lindley Silt Loam	Des Moines, Ia.	5.70
40	Sharkey Clay	New Orleans, La.	5.98
4	Chester Loam	Jenkintown, Pa.	6.12
8	Fargo Clay Loam	Fargo, N. D.	5.83
46	Unidentified Sandy Loam	Denver, Colo.	6.07
25	Miami Clay Loam	Milwaukee, Wis.	5.74
26	Miami Silt Loam	Springfield, Ohio	5.48
21	Marshall Silt Loam	Kansas City, Mo.	6.05
44	Wabash Silt Loam	Omaha, Nebr.	5.68
2	Bell Clay	Dallas, Tex.	5.93

effect that "soil characteristics, rather than differences in the composition of the ferrous pipe materials, appear to determine the type and extent of the corrosion observed." The test on protective coatings indicated that many of the coatings in use today are unsatisfactory in bad soils. Soil stress is an important factor in the life of protective coatings on underground pipe lines. Only a portion of the soils of the United States are seriously corrosive. The need for protecting buried lines varies with their location. It is advisable to secure information as to soil corrosiveness before selecting protection for pipe lines. Under some conditions it is advisable to protect only parts of the line. Several methods of identifying corrosive soils have been developed. For certain types of soil, determination of the electrical resistance of the soil appears to furnish a basis for identifying those which are corrosive. The Bureau of Standards is accumulating a large amount of data in which is shown the performance of protective coatings as related to soil conditions. In addition to field tests of proprietary coatings an attempt is being made to determine the fundamental requirements for a satisfactory coating and a quick method for determining whether a new coating will meet these requirements. The article by K. H. Logan of the Bureau of Standards[24] is a brief review worth reading.

The American Gas Association, in coöperation with the American Petroleum Institute, Bureau of Standards, and manufacturers of protective coatings, also has under way a test on protective coatings. During 1929 and 1930 forty-two coatings, represented by some 2300 two-foot sections of 2-inch pipe, were buried in fourteen different locations. Four hundred and sixty-two of these specimens were recently removed for inspection and study. Dr. Ewing's progress report at the April meeting of the Distribution Engineers indicates, as would be expected, that paints and thin coatings are decidedly inferior to heavier coatings; thickness is an important factor; there is no apparent justification for ever using a coating less than 0.01 inch in thickness; certain fabrics rot rapidly; certain coatings are badly distorted by soil stress; on the whole, coat-tar pitch is somewhat superior to asphalt; and enamels should be relatively hard in order to resist the action of the soil. Measurements and tests, which have so far been made upon the first set of American Gas Association specimens, indicate that it may be possible to determine the protec-

[24] Logan, K. H., "Some Misconceptions of Soil Corrosion," The Oil and Gas Journal, August 29, 1929.

tion afforded by the pipe coating with reasonable certainty by measurements of its conductivity after it has been buried.

The American Petroleum Institute has undertaken a similar investigation. Forty-six different coatings, represented by something over 2200 samples were buried during the past year in sixteen different soils. Dr. Scott's recent progress report indicates the rapid changes taking place in the manufacture and application of protective coatings for, of the 25 sponsors of the 42 coatings under test by the American Gas Association and the 29 sponsors of the 46 coatings under test by the American Petroleum Institute, only 20 are common to both groups. Of the 88 coatings under test in 30 different soils only six are exact duplicates.

"A Study of the Various Kinds and Types of Uuderground Pipe Coatings" by O. K. Smith covers an investigation of various kinds and types of pipe coatings by the Chemical Department of the United Light and Power Engineering and Construction Company, Davenport, Iowa, starting in 1925 and continuing through 1930, covering 31 combinations. They have come to the conclusion that a wrapped pipe, using one or more coats of hot enamel and one wrapping of a suitable wrapper is the most efficient coating which they can put on for their condition.

The U. S. Reclamation Service investigation on the "Behavior of Various Metals in Presence of Alkali" points to the same conclusion, but is more limited in scope.

Tests conducted by the U. S. Department of Agriculture, Bureau of Public Roads, the California Highway Commission, the Wisconsin Highway Commission, and others on the corrosion of many thousand culverts are interesting, but are really a combination of atmospheric corrosion tests, underwater corrosion tests, and soil corrosion tests, as the factors controlling the corrosion of culverts are different from those controlling regular soil corrosion and are really a combination of the three with concentrated action taking place at the bottom.

"Movement of Pipe in Sub-Soil" by W. M. Henderson, Los Angeles Gas and Electric Co., covers the first stages of a proposed investigation on the extent to which a pipe is free to move in sub-soil and involves primarily steel pipe with rigid joints, both plain and coated. When their experimental procedure proves satisfactory it is intended to make observations on pipe that has been buried for a period of years. The effect on coatings will be watched with interest.

Results of coöperative soil corrosion tests have accomplished much

toward a better understanding of the complicated soil corrosion problems and the manufacture and application of more durable coatings for use underground.

4. *Chemical corrosion* (*prevention*). Problems in chemical corrosion involve so many new and varied conditions that the two most important problems at the present time are the obtaining of more detailed facts and a better correlation of the various existing data. It is enough to say that the general classification of acid-resisting materials under oxidizing or under non-oxidizing conditions, and the recognition of the importance of dissolved oxygen in the latter case are steps in this direction. The recent rapid development in corrosion-resistant chromium and chrome-nickel alloy steels, such as USS 18 and USS 18–8, and protective linings holds interesting possibilities.

5. *Electrolytic* (*prevention*). Stray-current electrolysis presents a special phase of the corrosion problem. It is of special importance in cities where buried metallic structures come in close contact with electric railways, as for all practical purposes the electrolysis problem is due to the stray current from this source finding its way to water and gas pipe, underground metallic cable covers, and other underground structures. When the current leaves these structures through the earth, corrosion results. Roughly speaking, this means that under favorable conditions a continuous flow of half an ampere of current would remove in one year approximately ten pounds of the element iron. There is no evidence that a current flowing in a steel pipe injures it in any way as long as it does not leave the pipe. Electrolysis of interior of pipe is extremely rare.

The chief factors involved comprise the testing for and the control of the stray currents responsible for the corrosion. Bonding and the use of high resistance joints, are practical preventive measures. During recent years systematic study has been made of the problem, particularly by the Bureau of Standards (Their Technical Paper No. 52, 1915) and the Research Sub-Committee of the American Committee on Electrolysis (the 1921 report of the American Committee on Electrolysis).

IV. RÉSUMÉ

Material

Steel pipe is no longer an experiment—it is a modern necessity. Its use is steadily increasing both here and abroad. It has great strength and at the same time has a high degree of ductility and will

withstand, therefore, high pressures; it has high strength as a continuous beam, will withstand modern street conditions subject to vibration from heavy loads, sudden shock from adjacent blasting, distortion, caveins, wash-outs, and settlement due to filled-in ground, insecure foundations, or improper grading, water hammer and emergency pressures. Strong joints reduce leakage to a minimum, while long lengths facilitate and lower cost of laying by reducing the number of joints per mile. The wide variation in gauge, weight, and length, together with the large number of different types of joints now available, makes steel pipe adaptable to practically any service condition and allows the water works engineer the widest latitude in construction and design. As an illustration of the trend toward steel pipe, "Public Works," (61, 6, 1930), contains a summary of the amounts and different sizes of pipe laid in 1929.

There seems to be no question among water works engineers as to the reliability of steel. Many cities that have used other metals for years are now turning to steel in order to meet modern conditions. This has been especially true abroad.[25]

In this connection it is interesting to note the report of the Sub-Committee on Burst Water Mains to the Works and Stores Committee of the Metropolitan Water Board, London, dated December, 1930, which covers a survey of 7,200 miles of pipe lines under the Board's control. They state:

> "The subject of the action of soils upon cast iron pipes engaged the attention of engineers and chemists in the middle of the last century and it is interesting to note that there was then the same graphitic condition of the iron brought about by contact with certain kinds of soils. . . .
>
> "Steel pipes possess many advantages when protected and laid in such circumstances as the local conditions require. No one will dispute the fact that fewer joints are an advantage not only in the cost but by the reduction of the proportion of sources of leakage, although such long lengths are not always practicable in some of the London streets; nor will it be contended that a steel pipe is not an advantage, and in some cases a necessity, when high pumping heads have to be provided for.
>
> "In certain circumstances the superior strength of steel is, of course, admitted. Its protection is a matter to be considered in relation to local conditions.
>
> "That, however, does not exclude the use of steel but rather directs attention to the best means of clothing and protecting it.

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[25] R. H. Keays, "Some Notes on Pipe Practice in Europe," JOURNAL A. W. W., June, 1929, p. 820.

"Our investigation has resulted in the fullest disclosure of the circumstances under which the bursting of water mains takes place. We are satisfied that nothing further can be done so far as the mains now laid are concerned, except to inspect and overhaul these when any reasonable opportunities occur.

"As to the future, the relative merits of all available pipe-making materials must and will be considered in relation to the functions of the mains and the soil in which they are to be laid. The issue at the moment appears to concern the use of ordinary sand-cast iron pipes, 'spun' iron pipes, and steel tubes.

"We are satisfied that it is not advisable in view of the varying characters of the sub-surfaces throughout the whole of the Board's area to lay down hard-and-fast rules governing either the use of steel or case iron pipes. This must necessarily be the subject of careful consideration by the Board's expert adviser, due regard being had to the nature of the work to be performed and local circumstances.

"We are, however, of opinion that in future steel pipes adequately protected should in ordinary circumstances, with due regard to cost, be used for trunk and large high-pressure pumping mains in order to obviate as far as possible the occurrence of inundations due to fractures arising from circumstances more generally associated with cast iron.

"The effectual protection of the pipes, whether of cast iron or steel, against the attack of both the soil and water is of the utmost importance, for upon this protection depends the lasting qualities of the pipes. There is still room for further improvement in this direction, which we understand is continually taking place with satisfactory results.

"We again lay stress on the opinion that there should be the greatest measure of co-operation between the various statutory undertakers and the local authorities in the Board's area."

Another point of interest to engineers is the fact that steel mains give warning of approaching failure by leaks rather than sudden rupture, and can easily be repaired while under pressure. This point is of double importance in recent years and especially in congested districts, as it is not so much the loss from failure and cost of repair that is serious, but the incidental damages due to failure of other lines.

Steel pipe ordered to standard specifications such as A. S. T. M. A78–30 and A89–30 is the answer to many of the problems confronting the water works engineers of today. A constructive step in this direction is the proposed work of Sub-Committee 7-A on "Steel Plate Pipe."[26] Further five tentative specifications for steel pipe namely, (1) Forge-Welded Steel Pipe, (2) Electric-Fusion-Welded Steel Pipe, (3) Electric-Resistance-Welded Steel Pipe, (4) Riveted Steel Pipe, and (5) Lock-Bar Steel Pipe, which have just

[26] "A Summarization of Experience and Current Practice in Certain Phases of Steel Plate Pipe Line Construction," JOURNAL A. W. W., 22: 5, May, 1930.

been drafted by the American Society for Testing Materials, are being sent out for letter ballot and if passed at the June meeting will become tentative standards and will appear in the A. S. T. M. Year Book for 1931.

Alloy steels

It is only in the last few years that alloy steels have been commercially available in large tonnages. They are now being rapidly developed and used for many purposes. It may be sometime, however, before they are economically available for large installations such as pipe lines. The cost is bound to be above that of regular carbon steel. The economic solution of the corrosion problem is not necessarily through the development of more resistant metals, although much remains to be done along that line. As pointed out, the practical solution of this problem has frequently been accomplished by some treatment of the corroding media that will remove the cause of the trouble or by the application of suitable protective coatings.

Water treatment

It is sufficient to say in passing that conditions throughout the country are rapidly changing, and because of the transportation of water for long distances and various methods of treatment, it is many times difficult to draw hard and fast lines between the so-called hard water and soft water districts. Further, the wide-spread adoption of industrial water softening by the Zeolite process has also completely changed the corrosion picture as regards life of pipe in the hard water districts. Coöperative study has accomplished much. Practical application of preventive measures has prolonged the life of material under bad service conditions.

Exterior coatings

It is becoming better understood that the corrosion of pipe is an electrochemical process and that it is controllable under most conditions, by making the pipe metal as uniform as possible; by removing the conditions which set up galvanic action by giving attention to the surrounding soil and drainage; and, by separating the pipe metal from the corrosive influences when it is not possible to eliminate or correct them. This is best done by the use of metallic, non-metallic, Portland Cement or combination reinforced coatings with

asphalt or coal tar base materials. As local conditions vary widely, each type of corrosion requires separate consideration. Generally speaking, however, results under corrosive conditions are usually in proportion to the extent of the precautions taken. A good coating should protect the metal against the corrosive action of the ground water, action of acids, cinders, alkali, etc., and have the proper physical properties so as to withstand transportation, handling, laying, and soil stress, and not crack and check in cold weather, or run under the heat of the summer sun.

The main object of applying bituminous protective coatings is to exclude water and soil from contact with the metal, the best procedure being to first apply to the clean, dry surface of the pipe a suitable priming coat. The function of the priming coat is principally to afford a strong bond between the thicker, outer protective coating and the metal and is essential when subsequent coat is applied hot to the cold metal. It is of little protective value in itself, as is true of paints in general when placed underground. The recent paper by H. A. Gardner is of general interest at this time.[27] If the priming coat has been applied at the place of manufacture, which is preferable, the surface should be carefully cleaned and freshened in the field with a second priming coat of the same base material before applying the outer protective coating. The latter coating should be determined by a careful survey of the nature of the soil and drainage factors.

Protective coatings may be classified as (a) non-metallic, (b) metallic, (c) dips, (d) dips reinforced with saturated fabric, and (e) dips reinforced with heavy aggregate.

(a) Non-metallic coatings include those known as paints, bitumens, varnishes, and lacquers and are largely confined to the protection of pipe systems above ground where the tendency to peel and check may easily be repaired.

(b) Metallic coatings consist primarily of galvanizing (zinc) and are widely used for various purposes both above ground and below ground and with considerable success in certain soils, but if the soils are acid galvanizing is rapidly attacked and affords little or no permanent protection.

[27] Gardner, H. A., Director, Institute of Paint and Varnish Research, Washington, D. C., "Some Protective Coatings of Interest to the Gas Industry," delivered before the Joint Production and Chemical Conference, Philadelphia, Pa., May 21, 1931.

(c) Dipped coatings consisting largely of melted coal tar or asphalt are now, except under fairly good soil conditions, used principally as priming coats for heavier and thicker second coatings. It is important to use a base material of such consistency that it will neither run in the hot sun nor crack and check in cold weather and at the same time will form a good bond with the base metal and the heavier external coating. The harder type of bituminous enamels are more resistant to soil pressure.

(d) Dips reinforced with saturated fabric make a more substantial coating than dipping alone. The saturated fabric is usually wound spirally around the pipe under tension with sufficient overlap to make a tight joint. The finished coating is usually given a dusting of cement, lime, or sand to resist the solar heat or is wrapped with Kraft Paper. Variations of this type of coating are the dips with second coating of quick-setting enamel which have given a good account of themselves, or the combination of dip and saturated fabric (with additional protection secured by the use of an outer shield of thin sheet metal designed primarily to protect the coating from distortion due to severe soil stress).

(e) Bitumens reinforced with heavy aggregate (mastics) are more or less of a recent development and give a much harder, thicker, and more resistant coating than can be obtained by the use of reinforcing fabrics.

Seventy miles of oil lines protected with $\frac{3}{8}$-inch coating of this mastic have been laid in very corrosive soil in California. This type of coating, including the recently developed special Portland cement concrete, holds possibilities of being the most resistant external coating under bad soil conditions developed to date.

The Portland Cement Association Technical Data Sheet No. 28, December 1, 1930, "Concrete Covering for Protecting Pipe Lines," covers an interesting 7-year test on 2,000 ten-inch concrete cylinders in the severe sulphate soils and waters of Montrose, Colorado, and Medicine Lake, South Dakota. The results indicate that properly made concrete is a practical method of defeating corrosion for both large and small pipe under very severe soil conditions. It is essential that a dense concrete made of both fine and coarse aggregate and low-water cement ratio be used. They recommend a 1-inch minimum reinforced coating made of one sand, one and one-half gravel, and three cement; and the use of 2-inch by 6-inch mesh No. 13 wire, the reinforcement being carefully placed in the center of the covering

so that it will have at least one half-inch protective covering. The Temescal Water Company, Corona, California; the Dominquez Water Company, Los Angeles; and the Sweet Water Company, Laguna Beach, California; are apparently securing excellent results from concrete coatings in bad soil conditions, while several oil companies are using it with good success for underground transportation lines in bad soils.

The practical importance of making a soil survey in connection with the selection of the proper external protective coating is becoming more apparent.[28] It will mean in the future a saving by eliminating unnecessary protection and assuring proper protection where needed. It is now realized that failures have been due not only to poor application of the coating, but also to under-protection or poor selection of original coating material for the particular local condition.

In connection with the Field Application of Hot Bituminous Coatings to Underground Pipe Lines, the General Committee on Corrosion of the American Petroleum Institute, in coöperation with the Bureau of Standards and interested manufacturers, has prepared a code, in handy folder form, covering approved practice which might well be distributed to all those in charge of such work in the water works field. Copies may be secured at a very nominal price by writing directly to the American Petroleum Institute, 250 Park Avenue, New York City.

Interior linings

Internal protective linings present a smooth surface, reduce friction, protect the pipe from the corrosive action of the water, resist to a high degree the attachment of adhesive growths, and eliminate tuberculation, thus preserving the original carrying capacity of the pipe line over a long period of time. Impairment of carrying capacity of pipe with age is an important economic problem and one of prime importance to the water works engineer. Many papers have been presented on this subject over a period of time and much has already been accomplished. However, Europe seems to have made more progress in the way of actual adoption of protective linings as a more or less standard practice, as nearly all the large new steel lines are so protected.

[28] Richards, P. J., "Corrosion and Conservation of Underground Structures," Journal A. W. W., 23: 4, April, 1931.

Cement-lined and Talbot-lined pipe offer a practical means of preventing corrosion and loss of capacity due to internal incrustation or tuberculation. Talbot lining, an English development now available in this country, consists of a selected asphalt bitumen mixed with a chemically inert filler, and is applied to the inside of the pipe by the centrifugal process. The heated material is introduced into the interior of the pipe to be lined and the pipe is rapidly revolved in a manner that spreads and compacts the material uniformly over the surface of the pipe with considerable force, producing a uniform tightly-adhering lining of exceptionally smooth finish. It does not react with water in any way and leaves no taste. Steel pipe so lined was being used successfully in London, Liverpool, Manchester, Birmingham, Sheffield, Leeds, Aberdeen, Dublin, Glasgow, Singapore, as well as in Australasia, New Zealand, South Africa, Java, Argentine, and Uraguay. Other bituminous materials with suitable fillers can be applied centrifugally.

In Part V an effort has been made, through the application of Scobey's formula for dipped steel pipe, or pipe with internal lining, and Hazen and Williams' formula for dipped cast-iron pipe, to illustrate, by text and tables, the economic importance, through savings in operating costs, of using lined steel pipe.

Insurance rates and evaluation clauses

Proper protection against fire is an important problem. Insurance rates are based directly on the fire-protection security, that is, the town or city without proper protection usually pays the highest insurance rates. These rates are usually fixed by the Fire Underwriters and are based on many factors, one of which is pipe. Most of the insurance companies in turn base their rates accordingly. There seems to be no particular uniformity or agreement on suitable material. *The Standard Schedule for Grading Cities and Towns*, National Board of Fire Underwriters, Section 17, Reliability of Installation of Supply Mains, leaves the question of material open.

Facts no longer justify penalizing cities and towns protected with adequate steel mains. From the standpoint of reliability, the advantage would seem to be all with steel.

Coöperation

It is suggested that the American Water Works Association coöperate with the Fire Underwriters in a study of the life of steel pipe,

adequate protective coatings, and service rendered, and draw up a standard specification for steel pipe and proper protective coatings. It should be remembered that the average condition under which pipe must serve today is entirely different from conditions which existed some years ago. Pressures, vibrations, sudden shocks, settlement in filled ground, have all increased in recent years and place a much greater responsibility on large-diameter pipe lines. The numerous failures of water lines, particularly under city streets, as daily reported in the newspapers, are ample evidence that service conditions are in many cases so severe and taxing that the older mains cannot withstand the additional strain. That serious study must be given to this subject, if municipalities are to be saved the unfortunate and disturbing factor of torn up streets, costly repairs, interrupted service, and damage suits for flooded basements, is apparent to all those who have an interest in this subject.

Water is one of the few things we cannot afford to be without, regardless of cost. As cities grow and the consumption of water increases per capita, and sources of adequate water supply become more and more inaccessible, problems such as suitable material, stronger joints, higher factors of safety, suitable exterior coatings, interior linings, reduction in loss, etc., become, more and more, problems of mutual interest to manufacturers and water works engineers, consumers and the community at large. This is already a big problem. With the rapid concentration of population in cities plus natural yearly growth the problem has only started. Millions should be spent by various municipalities in providing an adequate water supply for the generations to come. Public officials, trade associations, and citizens generally should be made "water conscious." Pipe, naturally, will play an important part in this never-ending program. We cannot stress too strongly the economic value of co-operative study on the special phases of this subject.

V. ECONOMIC IMPORTANCE OF REDUCED FRICTIONAL RESISTANCE IN PIPES

As many of the larger cities have adopted steel as the material from which to form the main conduits for the water supplies, and many cities are using steel pipes in distribution systems to a greater extent each year, and as these steel mains transmit many hundreds of millions of gallons of water daily, often being forced through the pipe by pumps, the retardation effects of corrosion have an important eco-

nomic effect upon operating costs. In addition, many water works operators or designers desire to know whether the advantages secured by using steel pipe such as economy of first cost, reliability against fracture, reduced leakage at joints, smaller number of joints, etc., will be augmented by reduced frictional resistance or be counterbalanced in part or in whole by the increase in head caused by corrosion.

Mr. Alexander Potter stressed the importance of protective linings for pipes before the 13th Texas Water Works Short School at Waco, Texas, early this year, and Arthur T. Clark[29] presented an important paper on the effects of corrosion on the interior of pipes at the annual meeting of the American Water Works Association at Pittsburgh this year. These papers, together with many others appearing from time to time, contribute valuable data to the water works field.

It is with the idea of submitting data upon this question in condensed form that the following section has been prepared.

Effects of Internal Corrosion

The internal corrosion of water mains has not only all the bad effects of external corrosion, but in addition, by tuberculation, reduces the carrying capacity under a fixed head, or increases the head with a fixed discharge. In other words, internal corrosion not only depreciates the investment and increases the damage, repair and renewal costs, but in addition raises, in many cases, the operating costs by requiring more to pump the same amount of water. These statements apply to all pipes whether made of wrought steel, cast iron, or wrought iron. This may be illustrated by considering the conduits for the City of Rochester, N. Y., where cast iron, steel, and wrought iron were all used to convey practically the same water and the calculated values of "C" in Chezy's formula were as follows:

PIPE	NEW	25 YEARS	30 YEARS	35 YEARS
Cast iron, 24 inches	127	112	107	102
Steel, 38 inches	115	98	94	91
Wrought iron, 36 inches		79	78	77
Wrought iron, 24 inches		72	71	69

[29] JOURNAL A. W. W., October, 1931, page 1565.

Mr. F. C. Scobey, in referring to these lines, but omitting that of cast iron, states in regard to the wrought iron line that, "The indicated capacity for the reaches of Conduit No. 1 was appreciably below that called for by the writer's formula." Referring to the steel lines, he shows that their capacity was from 4.2 to 15.6 percent above that called for in his formula. These differences may be due to the methods of constructing the pipe rather than such a radical difference in the rate of inside corrosion, for the tests made by G. M. Fair, M. C. Whipple, and C. Y. Hsiao, all of Harvard, on small wrought iron and wrought steel pipe at Cambridge, indicate an almost identical rate of change in discharge capacity, after the passage of various amounts of water, whether the pipe be made of steel or of wrought iron, and the relative effects were the same whether the water was between 36°F. to 77°F. or at 140°F. That is, the water works man may anticipate the same rate of corrosion of the interior of the pipe whether it is made of wrought steel or of wrought iron.

In the preceding table the value of "C" for steel pipe was smaller than that for cast iron both in the new and in the old pipe, but this difference was due entirely to the methods used at that time in making pipe from plates. The method was to make a series of short cylinders by riveting plates, and then connecting these cylinders with rivets; the numerous projecting rivet heads causing disturbances in the flow of water and thus reducing the carrying capacity. In the newer forms of wrought pipe made from plates either by welding or by lock-bar, with joints, when riveted, occurring about every 30 feet, the value of "C" is above that for cast iron pipe.

Flow factors

The relative effects of internal corrosion in wrought and cast pipes can be indicated by comparing the data assembled by probably the foremost authorities in their respective lines, i.e., Hazen and Williams for cast iron pipe, and Scobey for steel pipe.

Hazen and Williams in 1905 published the results of their exhaustive study on the flow of water through pipes, and enunciated a formula that is now used extensively in the water works field, having proved its value by years of service.

In the introduction to their hydraulic tables they state:

"The gradual roughening of the interior of cast iron is one of the most familiar of water works phenomena. It is also one of the most difficult to compute. In a general way, it may be said that in a series of years, which is not long com-

pared with the total life of pipe, the roughening of the surface and the reduction of the area through rusting and tuberculation reach such an extent that twice as much head is consumed in sending a given volume of water through it as was the case when the pipe was new."

Referring to steel pipes made by riveting plates together, for this was the standard practice when their treatise was presented, they state:

"Steel pipes tuberculate and corrode in much the same manner as cast-iron pipes. On account of the rivets and in-and-out joints, the average value of 'c' is lower than for cast-iron pipe. The data at hand indicate a value of 110 for new pipe, decreasing in the course of about ten years to 100. For older pipes, as far as present data go, steel pipe of a given age will carry the same quantity of water as cast-iron pipe of the same size and ten years older."

Later, F. C. Scobey, Senior Irrigation Engineer of the Division of Agricultural Engineering, U. S. Department of Agriculture, after an exhaustive study of a large amount of data on the flow of water through steel pipe, based on 1178 observations of 198 reaches of pipe, gave to the engineering field a year ago a formula which places a new and efficient tool in the hands of the designer of water lines. His formula covers riveted steel pipe as well as the newer forms (such as, lock-bar, hammer-welded, and electric-welded pipe, which were unknown except possibly lock-bar at the time Hazen and Williams wrote their treatise).

Where Hazen and Williams' formula may be expressed as:

$$V = C\, R^{0.63}\, S^{0.54}\, 0.001^{-0.04}$$

Scobey's formula is:

$$V = K^{-0.53}\, 1000^{0.58}\, S^{0.53}\, 4^{0.58}\, D^{0.58}$$

or as Scobey expresses it:

$$V = K^{-0.53}\, H^{0.53}\, D^{0.58}$$

V equals velocity in feet per second; C equals Hazen and Williams' flow factor which changes for different periods of time; R equals hydraulic radius in feet; S equals hydraulic slope of grade in feet per foot of length; K is Scobey's frictional factor; H is frictional head in feet per thousand feet of pipe; D equals diameter of pipe in feet; further, Scobey introduces the very valuable factor of time which affects the value of K, and as a result of his work to date suggests

that a new K can be used with a time factor. That is, K prime equals Ke^{mt}, in which "t" is the elapsed time and "m" is a variable, depending upon the corrosiveness of the water. His tentative recommendations are for eastern waters that are active from the corrosive point of view, in which case "m" equals 0.015, while for waters known to be relatively inactive "m" is equal to 0.01. In this case, "e" is the base of the Napierian logarithm. Further, he permits a variation of his formula due to the change in the viscosity of the water, due to temperature changes, but this matter is treated in *Technical Bulletin No. 150.*

Flow through unlined pipe

Hazen and Williams assign certain values of C for different sizes of pipe for various years, and when considering a similar active water Scobey varied the value of K by multiplying it by $e^{0.015t}$.

In order to make a comparison of the various heads consumed or the pumping powers required to deliver a fixed volume of water, calculations have been made for a 24-inch pipe with a velocity of 2.5 feet per second. The data presented by Hazen and Williams are used for cast-iron pipe and that by Scobey for sooth interior steel pipe. These calculations show that: with new pipe, cast iron consumes 5 percent more head than the steel pipe; after 5 years this difference is increased to 13 percent; after 11 years to 21.5 percent; in 19 years, 28 percent; in 29 years, 34 percent; and after 42 years over 37 percent.

In a great percentage of cases internal corrosion of a pipe is of greater economic importance to the water-works field than exterior corrosion. The data supplied by Hazens and Williams' formula indicates that a 24-inch cast-iron main after being in use with eastern active waters for 25 years would, with a velocity of 2.5 feet per second, have an increase in the loss of head of 86 percent, while with Scobey's formula for smooth-bore steel pipe, the increase will be but 46 percent under the same conditions.

The advisability of proper protection for water pipe interiors has long been recognized, for as Scobey states:[30]

"All iron or steel pipes should be chemically protected with a coating that forms the true interior surface, at least during the first years of the life of the

[30] Scobey, Fred C., "The Flow of Water in Riveted Steel and Analogous Pipes," U. S. Department of Agriculture Technical Bulletin No. 150, January, 1930.

conduit. . . . . Most coatings are of appreciable body and tend to submerge minor differences in original surfaces. . . . . Obstructions—rivet heads, plate offsets, blisters, tubercles, etc.—have much greater influence than appears possible to the eye. It has long been known that an occasional obstruction has greater effect than might be expected from the combined effect of a number of obstructions. A pipe with one or two continuous longitudinal projections such as are found on lock-bar pipe or the smaller but rougher beads in most electric-welded pipe will be considered the same as a pipe without such projections. Water flowing at 'commercial velocities' does not follow straight lines, and there must be some retardation due to these beads, especially in a sinuous line where considerable 'roping' of the water prism takes place. The uncertainty as to the amount of the retardation and the fact that it is overshadowed by the probable condition of the pipe coating seems to justify ignoring these projections."

Further, it is quite obvious that an ideal protective lining should be sufficiently thick so that chances of penetration by pin holes, air bubbles, etc., are negligible, but any lining should withstand both corrosive and erosive action of the liquid handled.

The National Tube Company has been lining steel pipe with a special cement and has conducted experiments to determine the most satisfactory method of application. In addition, the same company has installed equipment for lining steel pipe with a special mastic by an English process known as Talbot lining. This non-corrosive lining about $\frac{1}{4}$ inch thick is applied hot centrifugally. One of the great advantages of thick linings applied centrifugally is the elimination of pin holes which penetrate through the lining to the wall of the pipe. Further, the centrifugal force eliminates the possibility of air bubbles existing next to the pipe surface.

Tests of lined pipe

A flow test line was erected by National Tube Company at its Versailles plant. The water after passing through about 1200 feet of 12-inch steel pipe Talbot-lined returned through the same length of 12-inch steel pipe cement-lined. About 100 feet from each end of both lines the pipes were tapped with a measured distance of 1000 feet. Before the lines were assembled with bell and spigot joints, each section of pipe was calibrated and it was found that the average diameter of the Talbot-lined section was $11\frac{5}{16}$-inches and that of the cement-lined section was $11\frac{7}{16}$-inches. A centrifugal pump circulated the water. Two lines of $\frac{3}{4}$-inch galvanized steel pipe transmitted the water pressures from one end to the other (1000 feet distant) where manometer tubes with mercury were used to measure the drop in pressure.

The Pitometer Company was engaged to make the measurements. Each pipe was traversed by a pitometer to determine the ratio of the average velocity to the central velocity, which were found to be 0.848 to 1.000 for the cement-lined section and 0.886 to 1.000 for the Talbot-lined section. Measurements of velocities were read on manometer tubes using bromoform (diluted when necessary with carbon tetrachloride). The losses in head and the velocities were read simultaneously on both the cement-lined and the Talbot-lined sections.

Mr. Beckwith of the Pitometer Company who had charge of these tests reported as follows:

	V	H	C
Cement lined	2.56	1.70	150
Talbot lined	2.60	1.63	158
Cement lined	3.58	3.21	149
Talbot lined	3.63	3.01	158
Cement lined	5.01	6.06	148
Talbot lined	5.08	5.65	158
Cement lined	5.63	7.57	148
Talbot lined	5.74	6.87	160
Cement lined	6.87	10.88	148
Talbot lined	7.01	9.95	160
Cement lined	8.20	15.38	147
Talbot lined	8.36	13.90	158
Cement lined	9.24	19.35	147
Talbot lined	9.42	17.40	159

Where V is velocity in feet per second
H is loss of head in 1000 feet
C is Hazen and Williams' retardation factor.

The late Mr. Hazen, after an examination of the above tests, wrote the author in 1929 as follows:

"The coefficients with the Talbot lining are very high, I think a little above my record for anything else, and speak very well for the material."

It will be noted that the value of C for the cement-lined section checks very closely with the value (150) as determined by Pirnie for

the new St. Petersburg, Fla., line, but is higher than that recommended by Scobey in 1920 for cement pipe (140). The improvements, however, in manufacturing, laying and jointing as well as the composition of the mix may be responsible for part of this difference, the balance being represented by an allowance made by Scobey of a reduction of from 10 to 15 percent in the carrying capacity due to accumulations of slimes forming shortly after the pipes are in service.

Scobey at the same time presented data regarding the resistance to flow through cement and concrete cylinders, and offered a formula for the loss in head as follows: $V = MH^{0.5} D^{0.625}$ in which M for the modern cement or concrete pipe is 1.75 which would give approximately a value of 140 for C in Hazen and Williams' formula.

It should be noted that the test lines at Versailles, Pa., were without vertical or horizontal curvature, and therefore in the following calculations tentative values of C for cement-lined pipe are taken as 145, and for Talbot-lined pipe as 155 when Hazen and Williams' formula is used, and when Scobey's formula is applied the tentative values of K are taken as 0.275 for cement-lined pipe and 0.245 for Talbot-lined pipe.

Basis of tables and curves

To show the economic importance of a non-corrosive and non-tuberculating lining when handling active waters, a series of calculations have been made and the results tabulated and plotted. In these calculations it has been assumed that a 24-inch diameter pipe is used and that the water has an average velocity of 2.5 feet per second, delivering 7.85 cubic feet per second or a little over 5,000,000 gallons per day. With the cement-lined and Talbot-lined pipe a reduction of $\frac{1}{2}$-inch is made in the diameter to allow for the thickness of the lining so that the average velocity in lined pipe is 2.6075 instead of 2.5.

Further assumptions are made that unlined cast-iron pipe will be subjected to the deterioration due to age as is shown in Hazen and Williams' tables; that unlined steel pipe will deteriorate as indicated by the Scobey formula for active waters; and that the value of C as 155 or of K as 0.245 for Talbot-lined pipe will remain constant.

Permanence of discharge values of lined pipe

The only bases for the assumption that the value of discharge for Talbot-lined pipe remains constant with age are private reports from

England that indicate that after six years of use with active waters the value of K is less than 0.245 or for C is over 145, and a comparatively short-time test of Talbot-lined pipe conveying water containing phosphoric acid and carrying in suspension a large amount of finely-divided mineral matter while still in progress indicates that after 3000 hours the Talbot-lined pipe is as good as new while the centrifugally cast cast-iron pipe was penetrated in about 2500 hours.

At the Versailles plant Talbot-lined pipes are used to convey dilute sulphuric acid in the process of electroplating with zinc. Although the ends of the pipe have been eaten away by the drip of the acid solution, the lining has remained in perfect condition after two years of use. Similar results have been obtained with Talbot-lined pipe handling the acid water from coal mines.

It is with the understanding that the following tables and curves are compiled using the aforementioned assumptions and are not to be considered as based on well-established facts, that the data are placed in tabular form so as to illustrate the magnitude of the economic loss that results from the corrosion or tuberculation of the interior of water pipes.

It should be noted that Hazen and Williams' coefficients are based upon sand cast cast-iron pipe coated with the dips, etc., in use at the time that their records were made. It is unfortunate that the necessary information is not available so that comparison could be made with pipe protected by the more recent dips, etc., and with pipe centrifugally cast in sand or metal moulds.

It will be observed that no allowances are made for deposition of silt or mud in mains, for this is such a variable factor, and will affect all pipes in a similar way.

Explanation of tables and curves

In the following tables the word "unlined" is used to represent the usual dip, etc., as was applied to cast-iron pipes when Hazen and Williams made their studies and as applied during the present time to steel pipes.

In these tables the heading figures represent the years of service. The first three lines in each section represent the loss of head in feet in 1000 feet of pipe. The horsepower was calculated by converting the foot pounds of work done in overcoming the loss of head when 7.85 cubic feet of water are delivered per second through a 24-inch pipe (where lined, the net inside diameter would be 23.5 inches) multi-

plied by 490 pounds (the weight of 7.85 cubic feet of water) and the product multiplied by 60 percent which is considered as a fair overall operating efficiency of a pumping plant. As it was assumed that the average velocity for a year would be 2.5 feet per second, the figures representing the horsepower were multiplied by 8760 to get the horsepower hours per year. (Single horsepower hours are given in table merely for checking purposes.)

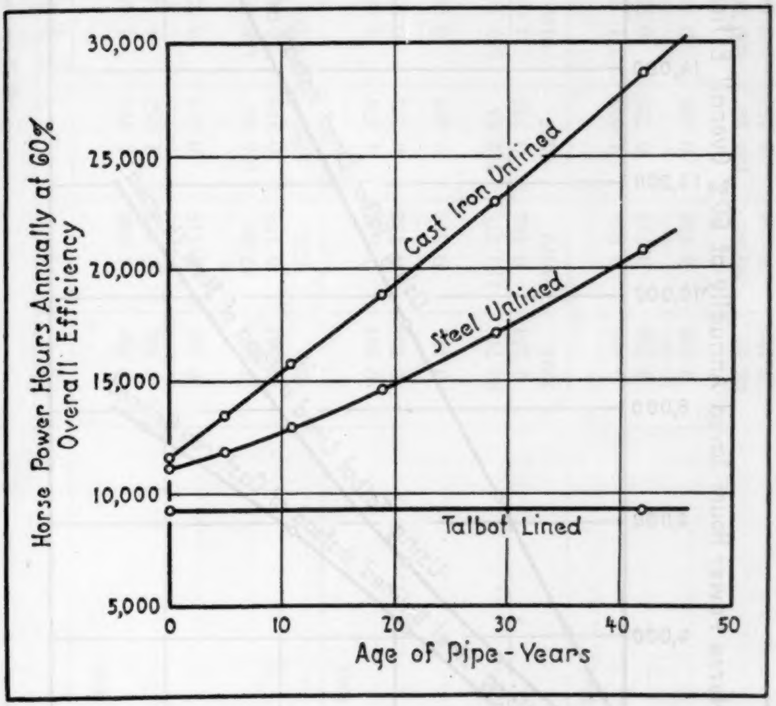

FIG. 3. HORSE POWER HOURS USED ANNUALLY IN PUMPING 7.85 CUBIC FEET PER SECOND OF ACTIVE WATER (APPROXIMATELY 5,000,000 GALLONS DAILY) THROUGH 1000-FEET OF 24-INCH UNLINED CAST IRON OR STEEL VS. TALBOT LINED STEEL

Figure 3 represents graphically the number of horsepower hours that would be required to pump 7.85 cubic feet per second through 1000 feet of 24-inch pipe and is based on the tabulated data.

Figure 4 shows the last lines of the tabulated data. The character of pipe or lining requiring the smaller amount of power is named first in the title of each curve.

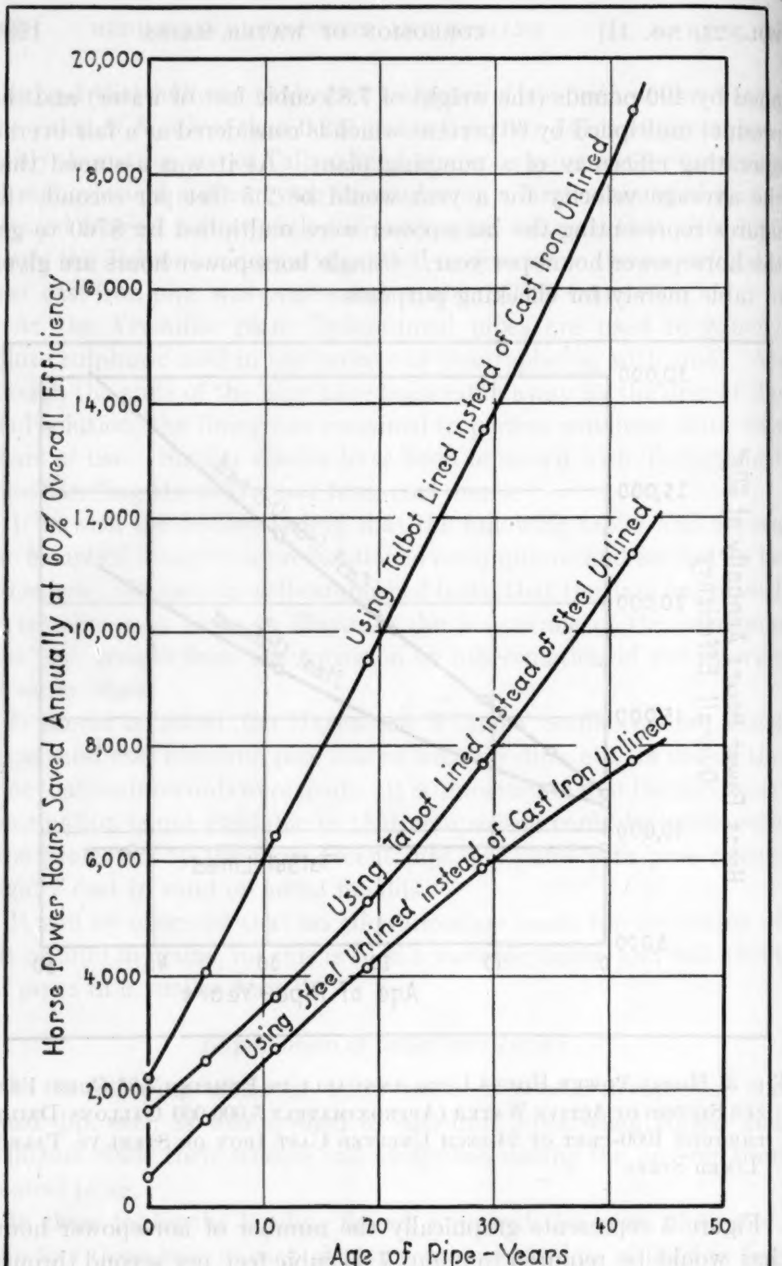

FIG. 4. DIFFERENCES IN HORSE POWER HOURS USED ANNUALLY IN PUMPING 7.85 CUBIC FEET OF ACTIVE WATER (APPROXIMATELY 5,000,000 GALLONS DAILY) THROUGH 1000-FEET OF 24-INCH UNLINED CAST IRON OR STEEL VS. TALBOT LINED STEEL

TABLE 1

24-inch pipe delivering water at a velocity of 2.5 feet per second

	YEARS					
	0	5	11	19	29	42
Loss of head per 1000 feet in feet						
Cast iron unlined	0.894	1.036	1.218	1.453	1.766	2.196
Steel unlined	0.851	0.918	1.003	1.133	1.314	1.599
Differences, feet	0.043	0.118	0.215	0.320	0.452	0.597
Foot pounds	21.07	57.82	105.35	156.80	221.48	292.53
Horsepower at 60 percent	0.064	0.175	0.319	0.475	0.671	0.88
Horsepower hours per year	559	1535	2796	4163	5879	7766
Loss of head per 1000 feet in feet						
Cast iron unlined	0.894	1.036	1.218	1.453	1.766	2.196
Talbot lined	0.723	0.723	0.723	0.723	0.723	0.723
Differences, feet	0.171	0.313	0.495	0.730	1.043	1.473
Foot pounds	83.79	153.37	242.55	357.70	511.07	721.77
Horsepower at 60 percent	0.254	0.465	0.735	1.084	1.549	2.187
Horsepower hours per year	2224	4072	6438	9496	13,567	19,160
Loss of head per 1000 feet in feet						
Steel unlined	0.851	0.918	1.003	1.133	1.314	1.599
Talbot lined	0.723	0.723	0.723	0.723	0.723	0.723
Differences, feet	0.128	0.195	0.280	0.410	0.591	0.876
Foot pounds	62.72	95.55	137.20	200.90	289.59	429.24
Horsepower at 60 percent	0.190	0.290	0.416	0.609	0.878	1.301
Horsepower hours per year	1665	2537	3642	5330	7688	11,394

The yearly horsepower hours given in table 1 were plotted and from interpolated points summations were made which are shown in table 2.

In table 2, the second one of the pipes compared is the one that would consume the least amount of power to transmit the water.

The figures in table 2 can also be read as the approximate number of cents saved for the different intervals of time per million gallons per day per mile of line for each cent charged for a horsepower hour, provided that average rate of flow be equated to the basic velocity of 2.5 feet per second in a 24-inch diameter pipe. Where waters are corrosive the time intervals indicated in the two preceding tables will be lengthened, while with inactive waters the same intervals will be shortened. Thus, Scobey indicates that two years' use of pipe with active water is equivalent to three years with relatively inactive water; four years to six; ten years to fifteen, etc. In other words, it will take 50 per cent longer for a steel pipe carrying relatively inactive waters to corrode than if active waters were transmitted through the same pipe. It is believed that the same will hold good for cast-iron pipe.

TABLE 2

Total differences in power consumed during stated periods of service, in horsepower hours per 1000 feet of pipe

	YEARS				
	5	10	20	30	40
Comparison between:					
Unlined cast iron and Talbot-lined	16,000	41,000	120,000	240,000	401,000
Unlined steel and Talbot-lined	11,000	26,000	71,000	139,000	231,000
Unlined cast iron and steel	5,000	15,000	49,000	101,000	170,000

Necessity of research on lined pipe

The manufacturers of various kinds of pipes and of protective linings are making every effort to place upon the market materials that will reduce the losses caused by the deteriorating effects of age upon the interior of the pipe, but the great need is comparative data from many communities. A protective lining that has proved to be satisfactory for a water in California may be unsuitable for one in

Pennsylvania. In New York City alone, an interior protection may be satisfactory with Croton Water, but be a disappointment when conveying Catskill water.

There are few communities with water supply lines that are affected by corrosion or tuberculation or both, that would not be warranted, when making new installations, to place in these lines some form of improved protected pipe, especially when the cost of such lines when laid would probably not exceed some of the older forms of pipe that are protected only by a dipped lining. On such installations records should be kept of the changes in the frictional factor with age, as well as any changes in the character of the water transmitted.

Such records as have been made by the City of Rochester, N. Y., although covering but two kinds of pipe, and several kinds of outside and inside protective dips have been a valuable contribution to the fund of water-works knowledge.

Many cities are closely watching the loss caused by leakage and waste, but often neglect the important loss caused by increased pumping costs, or are installing new unlined mains because of reduced delivery on the old existing mains without proper consideration of the probable future condition of such lines.

When considering the amount of research work that has already been done by the American Water Works Association on other problems, it would appear advantageous to many of its members to give officially impetus to a movement to investigate thoroughly the economic value of interior-lined pipe.

DIVERSION OF WATER WORKS FUNDS

By Howell Wright[1]

The Board of Directors last January took definite action with respect to one of the most important problems in the municipal water works field. The President was empowered to appoint a "Special Committee on the Diversion of Water Works Funds" to have full authority to study this question, to investigate and report with recommendations; to secure necessary funds from private and other sources; to make expenditures of funds so secured; to appoint and employ such persons to perform such work as may be deemed necessary and to fix rates of compensation, all subject to the approval of the Board of Directors and to make a preliminary report at the 1931 Convention and a final report at or before the 1932 Convention. This paper by the Chairman of the Committee is in the nature of a preliminary statement to emphasize the scope and timely importance of the investigation both as to the law and the facts.

Organized communities endeavor to secure an adequate supply of water, as a rule, either through municipally owned and operated water works, or those controlled by private capital. Some expression, at least of the political wisdom of municipal ownership of water works, which is a question for the state legislatures and not the Courts, may be found in the fact that of the more than 9000 water works in this country supplying not less than 10,000 communities, only 30 percent are privately owned while 70 percent are municipal. In this brief discussion we consider only municipal water works.

It seems to be a fixed principle that the legislature may delegate to municipalities the right of regulation and control of water works owned and operated by the municipalities. The extent to which such power has been granted in the various states and the applicability of public utility acts to municipal corporations which own and operate water works are subjects in themselves for special investigation.

GOVERNMENTAL FUNCTION OR PRIVATE BUSINESS

In the exercise of this delegated authority it is important for us to inquire and to know in what capacity the municipality acts. Does

[1] Attorney at Law, Cleveland, O.

it act in its proprietary or governmental capacity? Is a municipal water works a public utility or a governmental function?

In general we find that "the construction, operation and maintenance of public utilities by municipal corporations for the benefit and convenience of their inhabitants ordinarily constitute the exercise of private powers" (C. J. 43–551). It is also generally held that a city, in the operation and maintenance of a water works system, acts in a proprietary and not in a governmental or legislative capacity, although it has been held that this rule applies only where water is supplied for the use of its inhabitants (C. J. 44–2304). We cite a few cases for purposes of illustration.

In a Pennsylvania case (31 Pa. 175, 183) it was held that "the supply of gas-light is no more a duty of sovereignity than the supply of water. Both these objects may be accomplished through the agency of individuals or private corporations. . . . . They stand upon the same footing as would any individual or body of persons upon whom the like special franchises had been conferred."

In a New York case however, Swanberg vs. New York (123 App. Div. 774, 775, 108 N.Y.S. 364) we read, "while it is true that the City . . . . in delivering water to private individuals acts in a sense as a private corporation, yet the duty and obligation of the municipality to afford fire protection and to safeguard the public health through a pure and wholesome supply of water makes the maintenance of the water system more of a duty owing to a public or municipal corporation." The same doctrine is expressed in David vs. Portland Water Committee, 14 Oregon 96, 123. 12 P. 174. In the same breath, however, we read in an Illinois case (Eastern State Normal School vs. Charleston, 271 Ill. 602, 111 N.E. 573) that "although the business is carried on for the public advantage and is impressed with a public use, in supplying water for the use of its inhabitants for domestic and commercial purposes, a municipality is not exercising a governmental power but acting as a private corporation."

From these few citations it can be seen that this question is not always an easy one to determine. It has been declared to be a relative question in David vs. Portland Water Committee (14 Or. 96) in the following language. "Public parks, gas, water and sewage may ordinarily be classed as private affairs, but they often become matters of public importance, and when the legislature determines that there

is a public necessity for their use in a certain locality, I do not think they can be designated as mere private affairs. That is a relative question," says the Court. We may also add, however, that it is a question in its manifold ramifications for further study and investigation regardless of the opinion stated in 19 Ruling Case Law, Section 69, Water Works, that, "It is almost universally conceded that the operation of a water works system, by which a supply of water is brought into a town and distributed by means of pipes to the residences and places of business of the inhabitants, is undertaken by a municipality in its private or proprietary capacity."

DISCRIMINATION

It is a well established rule that neither public nor private corporations may discriminate between members of the public with reference to rates and terms of service. This no longer admits of controversy.

Acting in a proprietary capacity a municipality operating a utility has the same freedom of action as a private utility corporation, but it is also subject to the same restrictions as to practice of discrimination in rates and service. "A municipal corporation," then, "operating a water works for profit is . . . . . like a private corporation engaged in the same business, bound to supply water at reasonable rates, and is subject to the control of the legislature in determining rates in the same manner as a private corporation" (19 R.C.L. Page 765).

For purpose of illustrating the rule just laid down we cite here several decisions from different states and which we hope will also show how "discrimination" is related to our subject. The cases cited deal with free service furnished by municipal water works. It seems hardly necessary to refer to such service by private water companies, as free service has been largely eliminated from the operation of privately owned water works. And it may be said with authority that while there are some Court decisions which support the right of a municipality, in operating a public utility, to give free or reduced rates to public, charitable or religious institutions or for public purposes generally, the Commission rulings are generally to the contrary, holding that such free and special rates are unjustly discriminatory. We are of the opinion that there is no such thing as "free service" or "free water," It must be paid for by someone.

SUPREME COURT DECISIONS

In an Oklahoma case (1916) Fretz vs. Edmond (66 Okla. 26, L.R.A. 1918 C. 405) the Supreme Court held that the donation of water by a municipality to a State Normal School did not constitute an unjust discrimination against a citizen, taxpayer, and a water consumer of the city who was required to pay a fixed rate for water used by him.

We find in a Pennsylvania case, 1922 Consolidated Ice Co. vs. Pittsburg 274 Page 538, (118 Atlantic 544) that the fact that a municipality operating a water plant supplied itself with free water for fire protection, etc. and also supplied water free to certain public charities was not an abuse of discretion and afforded its pay customers no ground for complaint. In the case of East Illinois Normal School vs. City of Charleston (271 Ill. 602 111 N.E. 573), however, the Supreme Court held that the City of Charleston has no implied authority to undertake to furnish water from its municipal plant to a public institution for fifty years at a nominal cost, in consideration of its location in the city.

One of the most important Supreme Court cases on the subject of free water is Board of Education of Columbus vs the City of Columbus, Ohio, Number 20903, decided April 4, 1928. The question of "discrimination" is not raised, but the decision deals with constitutional questions as follows:

1. It declares unconstitutional and void as a violation of the rights conferred upon Municipalities by Section 4 of Article 8 of the Ohio Constitution a section of the General Code which prohibits a city or village or the water works department thereof from making a charge for supplying water for the use of public school buildings or other public buildings. (It overrules a previous contrary decision. 112 Ohio State 607.)

2. It declares that section of the General Code as unconstitutional and void in that it results in taking private property for public use without compensation therefor in violation of Section 19, Article 1 of the Ohio Constitution.

3. Municipalities devise the right to acquire, construct, own, lease and operate utilities the product of which is to be supplied to the municipality or its inhabitants from Section 4 of Article 18 of the Constitution and the legislature is without power to impose restrictions or limitations upon that right.

By virtue of this decision; the decision of the Supreme Court in the case of Village of Euclid vs Camp Wise Association (102, O.S. 145) and the case of the City of Cincinnati vs. Roettinger, a taxpayer, (105, O.S. 145) the law in Ohio with respect to free water is as follows:

1. Surplus revenues derived from water rents may be applied only to repairs, plant extensions, interest and to the liquidation of indebtedness, if any, and cannot be diverted or used for other municipal purposes or operations.

2. No obligation rests upon any municipality to furnish water free of charge to public school buildings or other public buildings.

3. By virtue of the Camp Wise case no municipality is obliged to furnish free water to a charitable institution.

4. With reference to cemeteries, whether municipal or private, and also public libraries, there is not now, nor has there ever been, any authority in the law of Ohio permitting or requiring a municipally owned Water Works to furnish free water to them.

5. No obligation rests upon any municipality by virtue of any law of the State of Ohio to furnish free water for extinguishing fires, cleaning fire apparatus or for furnishing or supplying connections with fire hydrants or keeping them in repair for fire department purposes. (Sec. 14769 G. C. was declared unconstitutional in the Camp Wise Case.)

The Cleveland Appelate District (which includes the City of Cleveland) seems, however, to be exempt from the ruling of the Supreme Court in this case. This is due to the fact that a previous case (identical in every detail with the Columbus case) was carried through the Cleveland Court of Appeals to the Supreme Court in which the lower court declared the law constitutional. To overrule any court of Appeals on a constitutional question requires the concurrence of at least all but one of the Judges of the Supreme Court. In the Cleveland case the Supreme Court held the law constitutional by a vote of 2 to 5, while in the Columbus case the same law which was held unconstitutional by the Columbus Court of Appeals was held unconstitutional also by the Supreme Court by a vote of 5 to 2. We believe that *municipalities may charge* for water, therefore, furnished to public schools and other public buildings in all parts of Ohio except in the Cleveland Court of Appeals District and possibly in the 9th District. Because of the constitutional provision referred to above, the Ohio Chief Justice says "It would be difficult to describe or even imagine a more deplorable situation." A new taxpayers' suit has already been started to meet this peculiar situation in Cleveland.

PUBLIC UTILITY COMMISSIONS DECISIONS

We find the Public Utility Commissions generally inclined to rule against free municipal service or special rates as unjustly discriminatory. A much more extended investigation of the commission acts and ruling is necessary, however, as a basis for a complete and final report.

We find two Indiana cases (P.U.R. 1919 F. 38, 1919 and P.U.R. 1921 A. 1921) which hold that a charge by a municipal utility to churches and charitable institutions of a rate less than that charged other consumers for the same service was discriminatory. The Missouri Commission (1917 Mo.) P.U.R. 1917 D. 224 holds that the furnishing of free water from a municipal water plant to churches and schools in the city, while other consumers were charged for a like service constituted unlawful discrimination. Similar decisions have been reached by various commissions (including Montana, Maine, Connecticut and Wisconsin) with regard to the furnishing of water for fire protection purposes.

A summary of our position at this point is desirable. We find that 70 percent of the water works in the United States are municipal; as a rule a municipal water works represents the city in its proprietary or private business capacity and as such it has the same freedom of action as a private utility corporation, but is supposedly subject to the same restrictions as to practices of discrimination in rates and service; that both courts and commissions have ruled both for and against free municipal water for various uses, the controlling weight of the commission decisions being against the practice. These findings, however, are based only upon a preliminary study of the law. They do not represent conclusions resulting from long, careful and critical examination or legal research. To some degree, however, they show the trend of certain legal doctrines as to the use of water works funds for other than water works purposes. So much for the law.

ACTUAL PRACTICE

There is ample evidence that the practice of spending the water customer's money for other purposes of government and also of furnishing free water and free service is one of long standing. It has been spoken of as a "left over" from the days of political patronage. In the records of this Association we find that since 1895, forty papers have been read at our Conventions dealing directly or indirectly with free water and its abuses. We have all talked much about it.

In 1929 at the San Francisco convention in a paper on this subject we unfolded a brief story of the enormous diversion of water works funds and it applied to representative cities in more than a dozen states of the Union. We discussed at length the extravagant and wasteful free water policy then in force in Cleveland, Ohio. It is

still in force there due to the curious quirk in the Ohio Constitution as explained elsewhere in this report.

We believe there has been little, if any, change in this policy throughout the country since our last report. We are certain that contrary to existing laws, court decisions and commission rulings, "discrimination" is being practiced by municipal water works. Funds sadly needed for expansion, to meet growing community needs and demands for pure water, are being diverted for other purposes and such practices in some states are seriously entangled with proposals to increase water rates. In support of this opinion we offer 1929 evidence from municipal water works officials which has come to us through Water Works Engineering and other sources. We quote briefly from 20 states without giving names of cities or individuals.

Michigan—"No city department pays for water except the Street Railway."
Georgia—"Most every city department gets water free."
Illinois—"Water furnished free to some departments."
Illinois—"No charge to other departments."
Iowa—"Free to some departments in return for free rent."
Ohio—"Free to all—laws do not permit charge."
New York—"Free for fire hydrants, streets and sewers."
Minnesota—"Free to all departments."
Indiana—"Free for streets and sewers."
Oklahoma—"Free fire hydrants."
Massachusetts—"Free for hydrants and sewers."
South Carolina—"Free for all departments."
North Carolina—"Free for all departments."
Kansas—"Free to all departments—charge for hydrants and street sprinkling."
Ohio—"Free to all departments.
New Jersey—"No charge for street sprinkling and hydrants.
Iowa—"Free for streets, sewers, fires, hospitals, etc."
New York—"Free for all departments."
Colorado—"Free for sewers."
Connecticut—"Free for all services."
Connecticut—"Charge all city departments the same as private customers. In all public utility opinions failure to make such charges offends the law against discrimination" (P.U.R. 1927 E. Page 282).

So much for the actual practice. The facts enumerated as thus obtained can be used only as guide posts, but they indicate the need of careful and extended investigation in the field.

The President has appointed a committee for this purpose. It is our belief that this committee has it within its power to render a distinct service to the municipal water works business and to the

people in our cities and towns who are in need of and are demanding an adequate supply of pure water at reasonable rates.

DISCUSSION

James E. Gibson:[2] Mr. Wright has devoted so much time and thought to this subject that it is almost impossible to add anything to his work, but in the following remarks I simply want to endorse his views, and to add my own personal views.

I have been studying this matter for a number of years, and have tried to look at it from all angles, and without regard as to how I approach the subject I always wind up at the same point, and that is, that the municipally owned utility is no different in its functions from the privately owned utility, in not only the mechanical, but in its financial operation, accounting, etc. In other words, it is not a governmental function in the true sense of the word, but a proprietary one. The early common law view of utility corporations was that they had to render service at reasonable rates, but the more modern view had added "and without discrimination." Today the courts, public utility commissions, and economists agree that the first function of a utility is to supply service of the highest quality, and the second is to supply this service at reasonable rates to all parties involved without discrimination. It has been held repeatedly that the stockholders of the utility corporation must pay the same rates for service as other customers. If my thought is correct, therefore, a municipal utility is a corporation organized under proper statutes and owned by the municipality. It therefore becomes a stockholder in the utility and should pay for any service rendered it as a customer at the same rate as similar service rendered to other customers. Under the laws and rulings of our utility commissions, the utility corporations are permitted to earn, if possible, rates sufficient to pay all operating expenses, maintenance, depreciation, taxes, where required, with a reasonable rate of return on the investment to cover the hazard of the business; but they are not permitted to raise the rates to an unreasonable figure in an effort to make this earning. That is, if there has been an unwise investment in the utility, the stockholders of the corporation must forego their dividends. The same we believe holds true in the case of the municipally owned utility, except that usually these utilities are organized for the purpose of supplying

[2] Manager and Engineer, Water Department, Charleston, S. C.

service to the public living within the municipality, and without profit. Often, due to improper financing and poor engineering, they are not self-supporting, and it is necessary for the general tax fund to make up deficits. In many states this is recognized in the statute governing municipal corporation, and we believe this is the reason so many think a municipal corporation should be a revenue producer for the city. Another reason is that the utility is usually operated or managed directly by City Council, or through a board or commission more or less responsible to the political powers that be, and therefore there is no one willing to go before the courts to antagonize the political organization of the community, the feeling being that it is best to keep peace within the family.

A number of states, however, through the general laws are taking cognizance of this, placing the municipal utility under the public utility commissions of the state, and this has recently been done in New York State. Wisconsin did it a number of years ago. The decision of the courts and utility commissions, almost without exception, has been to prohibit the diversion of the funds of the water department to other uses of the city, and in this connection I would refer you to the decision of the Supreme Court of the State of Ohio in the case of Cincinnati vs. Roettinger 105, O.S. page 145. This was a case where the city proposed to raise the rate and use the proceeds accruing thereform for the use of the fire department.

Another instance showing the modern thought is that of the State of Iowa, Acts of the General Assembly, 1926, Section 16, which reads:

"Any member of the Board of Water Works, trustees, or any member of City Council, or any other person who shall, while there are outstanding obligations against said water works, divert, or attempt to divert, any of the income derived from the operation of the said water works by the city, for any purpose than that of maintaining, improving, extending, or paying the obligations of said water works, shall be held guilty of embezzlement and punished accordingly."

So able a lawyer as Associate Justice William H. Moody of the United States Supreme Court, as early as 1891, had the following to say regarding the Act under which the Haverhill, Massachusetts, water department is organized:

"This much I know; the main purpose which I desired to accomplish, carrying out in this respect the wishes of the Mayor and the leading members of the very able City Council then in office, was to separate completely the Water Department from all other affairs of the City. It was hoped thus that the Department

would be managed upon strictly business principles without regard to politics. To that end it was provided that the Water Commissioners should be appointed for a term of five years, that only one should be appointed each year, and that the City be left to pay for the water which it used like any other consumer. The power of management of the Department was vested exclusively in the Commissioners subject to removal by the City Council for cause."

This was forty years ago. How little progress we have made!

Referring to Nichols' very excellent publication Public Utility Service and Discrimination, we find repeated notations and decisions of the public utility commissions throughout the country ruling against the diversion of funds. For instance, we find the decision in West Virginia where the utility commission held that "the furnishing of free service to tenants in buildings belonging to the utility is descriminatory and a violation of the West Virginia statutes." In the case of Meek vs. Consumers E.L.&P.Co., Mo. P.U.R. 1915 A 956, we find the following:

"The practice of rendering free service to stockholders has been condemned as discriminatory and illegal."

This applies also to California, Illinois, Indiana, Michigan, Pennsylvania, South Dakota, and Wisconsin; and the New Jersey Commission remarked that "it has been repeatedly held that a stockholder was entitled to no preference or advantage in the matter of the rate he was to pay for service."

It is held almost universally by all utility commissions of the various states that public utilities company should not discriminate by furnishing employees and officers with free service even as a part of their compensation, the reason for this ruling being that the practice is obviously so susceptible to abuse. It has, however, been held perfectly lawful for public utilities other than common carriers to extend grants of free or reduced rate service to the Federal Government. It has been held, however, by one commission in particular that

"So far as possible there should be no concessions from the published rates of public utilities, but that if it were desired to make donations it would generally be preferable to make the donations in cash instead of in service."

In the case of a Massachusetts decision it was held that

"The arrangement with the Federal Government which compels the railroad companies to handle all increases in the mail business for a 4-year period without

increase in remuneration, constitutes to that extent an unjust burden upon ordinary intrastate traffic."

and in line with this the rates for water furnished the U. S. Government at its military reservation at 6 cents per thousand gallons was declared unreasonable and discriminatory, where it appeared that the expense of the service apportioned according to the number of gallons pumped for sale amounted to 8 cents per thousand gallons.

In a case in West Virginia, it was held that

"The inability of a town to raise by taxes enough to pay for water was held not to be a reasonable basis for rendering free water service."

It has been held repeatedly that the furnishing of electric light service to the city or municipality was a discrimination and that there is no "just and equitable reason why a water company should furnish free service to a city for sewer flushing, street sprinkling, water troughs, city buildings, cemetery, or any other purpose, and that the furnishing of free water to a city for fire protection purposes imposes an unjust burden upon the consumers who must pay through their rates for water used by the city."

In the case of the Augusta, Maine, Water District, it was held that:

"Furnishing free water for fire protection purposes is said to be unjust for the reason that the consumers are obliged to pay for privileges enjoyed by property owners whereas the consumer should pay for the water he uses in proportion to his use, and the property owner should pay for his protection in proportion to the taxable value of his property."

And, from a decision in Idaho,

"The owners of a valuable building in the heart of a city receive a considerably larger benefit from fire protection than the owner of a house in the outskirts of a city, whose ordinary use of water is not a proper index to the benefit received from fire protection."

In an Indiana decision, it was held that:

"The municipality should be required to pay for electricity, for the operation of its water plant, an amount equal at least to the cost of such service, since to furnish such service at less than cost places an unjust burden on other patrons."

The Wisconsin Commissions says:

"Municipalities should share the burden with other consumers of producing necessary revenue for a public utility."

In Connecticut, in the case of the Ansonia Water Company, it was held that:

"A water rate for fire service supplied to a municipality at less than cost is discriminatory and less than just, reasonable, and equitable."

In West Virginia, it was held that:

"The fair cost of public fire protection should be paid by taxation rather than by increased rates to the private water consumer."

In New Jersey it was held:

"An increased rate for water for city fire protection was recommended where the investment for hydrants, enlarged mains, and the additional property and expense necessary to maintain an adequate pressure for fire purposes demanded a higher gross return to avoid discrimination against other classes of service."

The foregoing citations in general refer to privately owned utilities, but it was held in the case of the Hammond, Indiana, Water Works, as in the case of private corporations, free service should not be rendered for city purposes. It was said:

"A municipal plant should have on file rates for street lighting and fire hydrant service and the amount due for such service should be paid by the municipality to the municipal utility in cash; that if the utility furnishes service to the town, either free or at an unremunerative rate, there is discrimination in that the ratepayers carry a burden which should be paid by the taxpayers, or must be made up by funds raised from taxation."

In a Montana decision it was held that:

"Free water service by a municipal plant for fire protection, sewer flushing, public buildings, and other public purposes is deemed to be unlawful discrimination in favor of the taxpayers and against the water consumers."

The Wisconsin Commission has repeatedly held in the case of municipal plants that:

"The City must pay the utility at a reasonable rate for all services rendered the city."

In Milwaukee it was held:

"A rate of a municipal water plant for public fire protection service which does not cover the cost of the service may not be an unjust discrimination against the users of general service, however, where the total revenue from the waterworks is insufficient to meet the operating expenses and provide a full return."

In a case of Maine, it was held that where a municipal electric light plant charges for street lighting an amount less than the cost of rendering that service, it was guilty of an illegal discrimination since it follows that the other consumers of the company pay a part of the bill for street lighting.

It was held in Wisconsin also that:

"A municipal water works must charge the regular rates to public buildings, since the law prohibits a private or municipal plant from making rate concessions."

It was also held that the street lighting service should return to the municipal plant its share of the cost of operation.

In Washington, in a case of a private utility, it was held that:

"A franchise ordinance requiring a water company to furnish free water for fire protection, street flushing, drinking fountains, and other public uses, puts an unjust burden upon the water consumers for the benefit of the taxpayers of the city."

The Supreme Court of the State of Washington in a decision said:

"The charge for constructing, operating, and maintaining a water system should be placed upon those who use water and not upon others; that the revenues to be received from the water plant are not monies of the city; they do not partake of the character of general funds; that the object of municipal ownership is to give the citizens the best possible service at the least possible price; that the citizens who are taxed to the extent of his use of the utility is entitled to all benefits; that the plant is maintained, the interest paid, and a sinking fund is provided for the bonds, the taxpayer—the water user—who is primarily burdened with meeting the maintenance, betterments, interest, and the cost of the system is entitled to the benefits. The surplus earnings of such a system therefore belong to the water users of a municipal water system and is to be expended for improving the water system so that it could be more efficiently operated. It can not therefore be diverted for the benefit of the taxpayers in reducing the expense of city government."

The Montana Public Service Commission, Spangler vs. Great Falls Municipal Water Plant, held:

"A city, as trustee of the water plant for all the consumers, should stand in the same relation to it as any private individual and should not receive service without compensation."

"The taxpayers," it held:

"Are reasonably entitled to be compensated for the use of the general credit of the city by being permitted to earn a return if they so desire upon the utility

property equal to the return which a private company would have to have, and which would constitute a fair return for such company. It is proper to make adequate provision for the future, though rates should not be so high as to recruit capital which ought to come from the taxpayers instead of the rate payers. Broadly speaking, the rate payers' duty is to contribute the necessary capital."

This we interpret to mean that, if the municipality issued the necessary bonds and paid for all extensions and improvements to the plant out of such bond issue sold, then it would be entitled to receive the necessary funds from the utility to cover the cost of this financing, including a reasonable profit. There may be some such instance in the country but usually this is not the case except in the beginning or in very large extensions or improvements.

In the case of Freeland vs. City of Sturgis, 226 N.W. 897, the Michigan Supreme Court held that plaintiffs sufficiently showed a right to enjoin city officials from using electric plant revenues to pay general expenses of the city.

"The plaintiffs are three resident taxpayers of the City of Sturgis. . . . It is alleged that they are users of a large amount of electrical energy; that the effect of the illegal action of the city is to compel them to pay a greater portion of the general expenses than they should pay and to practically exempt from taxation for such expenses large property holders who do not use any considerable quantity of light and power; that the plaintiffs may suffer further damage by the transfer of the utility fund to the general expense account of the city instead of using it for the proper rehabilitation of the plant and for retiring the bonded indebtedness; that, in the absence of a surplus or sinking-fund out of which to meet these expenditures, there is an ever-present danger of assessments against the plaintiff's property; that they are owners of industries which use large amounts of electrical energy; and that the misappropriation of the utility receipts by the city without retaining a fund for maintenance and for payment of the bonded indebtedness hazards their property and its earning capacity. These allegations show that a substantial injury threatens the plaintiffs, and are sufficient to confer jurisdiction at the suit of individual taxpayers."

In the case of the North Carolina Supreme Court, Board of Trustees vs. City of Henderson, 146 S.E. 808, it was held that:

"A water company's sale of its property to the city and the surrender of its franchise in effect repealed the ordinance granting the franchise, which required the furnishing of water to public schools; but the schools were held entitled to water free of charge until notice was given them of the city's intention to make a charge therefor."

In the case of Perrine vs. Bonaparte, 282 Pac. 332, it was disclosed that a city in Oklahoma complied with the state constitution and issued

bonds to purchase a water works system and taxed the citizens to pay the bonds. A property owner filed suit to reduce his taxes alleging that the estimated revenue, as determined by the taxing officials, for the water department of the city for the fiscal year, and the estimated needs for the operating expense of the water works department were such as to leave an operating surplus, which surplus was not applied or used for water works purposes, but was illegally and wrongfully applied. The Court stated:

"Neither statute nor Constitution specifically prescribes rates to be charged by municipally owned utility; neither statute nor Constitution specifically prescribes the purpose to which profits derived from municipally owned utility must be appropriated. . . . . The City of Oklahoma City fixes a rate for consumers of water, and the price paid for this service is based upon the amount of water used, and has nothing to do with the ad valorem tax which the Constitution requires to be levied and collected, for the purpose of creating a sinking fund to pay the bonds at maturity."

Later the same Court held, in Excise Board of Woodward County vs. Reid, 288 Pac. 458, that the Excise Commission erred in transferring proceeds from the operation of the municipal plant to the general sinking fund, saying:

"Apparently the excise board took the position that the proceeds from the operation of the municipal water plant should be used for sinking fund purposes, for it arbitrarily took for the estimated income to the general fund from other sources, $41,300, and placed it in the sinking fund. This Court has repeatedly held that neither the Constitution nor the statutes require the placing of a surplus from the operation of a municipal water plant in the sinking fund (Perrine V. Bonaparte, 140 Okl. 165, 282, p. 332), and under that holding the action of the excise board was without authority of law, and was a wrongful usurpation of power."

However, there seems to be a special act in the Oklahoma Constitution, for we find that in the Circuit Court of Appeals, Fifth Circuit, in St. Louis-San Francisco Rwy. Co. vs. Moore, 25 Fed. (2), 964, holds that:

"Under Section 27 of Article 10 of the Oklahoma Constitution a town of less than 2,000 population, operating waterworks for which it has issued bonds, is not required to comply with the provision of Okla. Comp. St. 1921, Paragraph 4507, which would require it to apply the surplus over the operating expenses of the waterworks plant to the interest and sinking fund of the construction bonds, the Supreme Court of Oklahoma having decided, in Kansas City Southern Rwy. Co. vs. Wood, 126 Okla., 272, that Section 4507 has no application to cities and towns of less than 2,000 population."

In the case of Somerset vs. Kentucky Utilities Company, 21 S.W. (2d) 817, it was disclosed that the city granted a franchise to a public utilities company with the agreement that the company should furnish free water to its schools and for use of its fire plugs. The franchise expired in 1925, but service was continued by the utility to the public generally and to the city for fire protection, and to the public schools, for which they billed the city. The city paid under protest and filed suit to recover. The court held that:

"There being no legal contract between the School Board and the utilities company covering the water service, the company could not have coerced payment of its bills by legal process. Neither could the board, as indicated, have required a continuance of the service without compensation. Hence, the company had the right to cut off the water under the circumstances. Under that condition, on demand the board paid the accrued water bills in order to have the service continued."

Therefore, the Court held that the city was not entitled to recover the amount and stated that it must pay for water used in its schools and through fire plugs.

The foregoing is composed mostly of citations from decisions of public utility commissions and courts and is not given you as original thought, but to show you the basis upon which I have offered my views and opinions.

My attention has recently been called to two cities in the commonwealth of Kansas where the earnings from the municipal power and water plant have been such that the cities in question have waived all real estate and personal property levies, and taxes, and have adopted a plan to retire the bonded indebteness of the municipality through the surplus earnings of the power and water plant. This is certainly rubbing it in to the water and electric light consumers pretty hard, and I can see no more justice in this position of the municipality than I can in taxing the butcher, the baker, and candlestick maker, and relieving all other individuals and all property from taxes.

Taxes are raised for the support of the fire department. The fire department cannot function without water supply and the cost of this water supply is made up in increased size of mains, valves, and fire hydrants, and the cost of pumpage of the water to supply the hydrants Water for public buildings is used for the transaction of all kinds of business—police, fire, municipal court, and the business of the city generally. Street flushing, sewer flushing, etc., is carried on for the purpose of sanitation, for which taxes are assessed. Now

the cost of a portion of the city's business includes not only personnel, street sweeping machines, etc., but the water used in connection therewith. This service is a proper charge that should be made to the divisions of the city government and payment therefore should be made to the water department in cash.

To expect, or to ask that this service be rendered the city without charge is certainly not good ethics or good business. It is not civic honesty. It is discrimination of the grossest kind, and places a double tax upon the water customer. It cannot be defended under any circumstance except that of political expediency.

How to correct the evil is another problem. It requires the development of a higher sense of civic honesty in public accounting. How we can bring about such a development I do not know. If we can get our legislature to place the supervision, rate making, financing, and operation of our municipal plants under the supervision of the state utility commissions such as they now have over private plants, I am quite certain the evil will be corrected. The only other way is for public spirited individuals in each community, or for the commissions in charge of the municipal utilities, to compel a proper accounting by recourse to the courts, and here it is difficult to get people to carry on such action.

H. P. Bohmann:[3] The City of Milwaukee is one that diverts money from the Water Fund to the General City Fund. Each year there is transferred $300,000 of the surplus earnings of the Water Department to the General City Fund. To date there has been transferred in this manner over six million dollars. It may interest you to learn how this practice came to be established.

The original construction of the water works was completed in 1874 and you may be surprised to learn that the population at this time was over 100,000. To finance the project bonds were issued in the sum of $1,600,000 bearing 7 percent interest. As the earnings of the department were insufficient to take up operating expenses and interest and sinking fund on this large bond issue, the annual deficit was made up each year by direct taxation against all real estate. During the first twenty-five years of the operation of the water works $1,800,000 were raised by taxation.

As the department grew and the earnings became greater, the an-

[3] Superintendent of Water Works, Milwaukee, Wis.

nual deficit became smaller so that the amount raised by taxation each year gradually became smaller and finally could be discontinued altogether. As the earnings became greater there was a surplus each year so that it was possible to reduce the water rate. About this time someone conceived the idea of turning over to the General City Fund surplus earnings of the Water Department to make up the amount raised originally by taxation. As I stated a moment ago, this amount was $1,800,000. Eventually this entire amount was wiped out by the annual transfers of surplus earnings so that another excuse had to be found for making such transfers. The excuse used at the present time is "Lost Taxes." If the Water Works were privately owned the City would drive a considerable sum each year in taxes which it does not get on account of the plant being municipally owned. The present transfer of $300,000 annually is to offset "Lost Taxes."

Some years ago the legislature passed a law legalizing the former transfers and permitting future transfers provided there is sufficient sum of money on hand to pay interest and sinking fund on the bonded indebtedness for two years. As our outstanding bonded endebtedness is only $55,000 there is always sufficient money to take care of these transfers.

The Water Department gets paid for the water furnished to city departments, public buildings, grounds and parks and also is paid a hydrant rental for all hydrants in service. The total amount collected from the various city departments in this manner amounts to $280,000 annually while annual transfers of surplus earnings is $300,000. Under the circumstances, it would not be wise for me to seriously object to these transfers, otherwise someone might get wise to the fact that the water works in very few of the large cities are being paid for water used by the city. The results would be that if the annual transfers of $300,000 would be stopped they might also stop the paying for water furnished city departments. The gain to the department would be only $20,000, so I think it is best not to wake a sleeping dog.

PERSONNEL PROBLEMS IN AMERICAN WATER WORKS

By C. A. Dykstra[1]

Public management recognizes today what is slowly being recognized in private management as well—that the personnel problem is one of the serious problems confronting both private and public business. The task of finding the right man for the right place is a serious one, and we must all be about it. In the field of water works it happens as in the case of no other public utility that our problems are, for the most part, problems in public rather than in private management.

It happens to be true, also, that with the coming of the so-called merit system into governmental operations, more and more water works authorities must take into account the fact that Civil Service Commissions have been set up in local jurisdictions and they have undertaken for public management what in private management is known as the employment and personnel problem. Whatever we do or say, therefore, in the field of water works personnel management, has to be considered in the light of our civil service laws and their administration. There is almost no considerable water works in the United States which does not have a definite and positive relation to what we call civil service administration. When the Superintendent of an American water works needs a new employe he finds himself compelled to consult the lists prepared by those who administer the classified service. These lists are made up after a statement of qualifications for the position have been set up and examination had to fill the lists. In some places the superintendent must take the first man on the list; in more places he is allowed to choose among the three highest; and in a few places he may pick from the lists as set up, at his discretion.

CIVIL SERVICE

It becomes futile, therefore, to discuss our personnel problems without discussing the methods and purposes of civil service com-

[1] City Manager, Cincinnati, Ohio.

missions and their general relations to the public service. It is fair to say that, more and more, civil service commissions are considering their problem to be one of recruiting the best material for public service.

With the new vision which our commissions are getting, it is entirely possible for our water works establishments to become adequately manned. Nevertheless there remains a feeling in the management of many water works that if it were not for the interference of what they always call "Civil Service," they could pick and choose employes much more wisely and set up higher standards for water works service. If this paper has any thesis at all, it is that under the enlightened methods now being pursued in many jurisdictions by civil service commissions and by close co-operation between our utility management and the city's personnel organization, it is quite possible to work out the employment problem satisfactorily and wisely.

I would go further and say that it is possible to rid ourselves of an incubus which hung heavily over our heads for many years. There still remain water works organizations in the United States which are the catchalls for our party managers. Here and there the so-called "municipal boss" still sends to our superintendents men who have rendered party service and who must be taken care of on this account. This traditional method of operation has no part in modern administrative practices and should be discouraged by everyone connected with American water works. To those who are constantly under political pressure a properly organized civil service commission is the best protection they can have.

Granted, then, that we are developing in this country better personnel practices, it becomes incumbent upon our water works administrations to so co-ordinate their work with civil service commissions that the best possible results can be obtained. This means first of all that our public personnel authorities must know the peculiar problems that confront the water works administrator. They must have careful statement of the kind of personnel service required, and they must equip themselves to do an excellent job of recruiting. It must become the business of civil service authorities to discover in our communities those who are sufficiently trained for water works service and those who have aptitudes in general for the public service, and so regulate the compensation schedules and the conditions of work in public administration that the classified lists shall contain the best possible material that the community offers.

COMPENSATION SCHEDULES MUST MAKE POSITIONS ATTRACTIVE

Much might be said on the general problem of classification compensation and recruiting. Suffice it for the purpose of this paper to indicate that it is possible to find excellent human material and reward merit through the standard personnel devices which are now being set up in our American cities. What we are up against even after we have found good human material is to so arrange compensation schedules, promotional opportunities, and the conditions of operation, that public service shall become more and more attractive. Thus we open the doors from time to time to a better grade of public employes and raise the standard of public service. Our water works are, par excellence, the devices which our communities use to bring them what we can agree is the most essential public utility service. The public is entitled, therefore, to the highest class of service from the finest personnel that can be assembled. We must strive more and more to give this service intelligently, honestly, promptly, and with unfailing courtesy.

THE EXPERIENCE OF CINCINNATI

As one of the proofs of the thesis that the standard personnel practice by civil service authorities fits the needs of American water works, may I submit the experience of the City of Cincinnati during the past year. It has been possible to modernize our water works administration, introduce mechanical devices of the latest and most approved type, cut down the personnel and reduce administrative expenditures not only without clash with our civil service commissions, but with their constant and enthusiastic aid and comfort.

On July 1, 1930, Cincinnati found itself operating with 39 meter readers reading an average of 150 accounts each per day. These readings were recorded upon individual field cards for each account. The field cards were returned to the office and then transferred to an office ledger card, after which the field cards were filed for the following month. The ledger card was then used for the basis of billing. The consumption was noted, together with the amount of the charge. These ledger cards were then passed to six billing machine operators who turned out the bills. The bill was a one-stub bill which performed the function of a cashier's stub. It was carbonized on the back in order to permit the copying of the billing data upon ledger sheets prepared monthly for each round of billing.

These sheets carried the folio numbers for all accounts, stamped by a numbering machine, the folio number being used to indicate the account.

All bills had been addressographed previously and then matched up with their corresponding position on the ledger sheets. The billing was done on regular billing typewriters with non-adding facilities, so that at the conclusion of any billing unit it was necessary to add these sheets to arrive at the total consumption billed and the amount of accounts receivable. The billing period ran from the 1st to the 25th of each month, on which date the delivery of bills by meter readers began. As payments were received the charges were posted to ledger sheets, and there was no proof of correct posting. The last date of payment was the 20th of the month. Because of the tremendous peak load of that date it was impossible to mail delinquent notices before the ensuing month's bills were due for delivery. Delinquent bills were therefore mailed out on the 10th of the following month for payment by the 15th, and this gave the office another peak load. On the 15th bills were prepared for the remaining unpaid account and turned over to turnkeys for collection or for shutting off of water.

MODERN PROCEDURE

It is obvious that this billing and collection procedure provided a good deal of duplication and was very costly. In a conference between the Superintendent of the Water Works, Mr. Hibbs, a representative of the Bureau of Governmental Research, and the City Manager, it was decided to apply modern procedure to our water works problem.

An inventory of the administrative division showed that there were 89 employes engaged in meter readings, posting of meter readings, commercial work, billing, collecting, and accounting. It was agreed to eliminate the transfer of meter readings from the field cards to the office cards, and to use field cards as a basis for billing. Meter books were substituted for field cards and the program arranged so as to transfer data from the former field cards to the new meter sheets in loose-leaf binders. A quarterly meter reading period was decided upon as standard, with the exception of large users whose accounts are still read and billed monthly, and domestic consumers in the old part of the city where leakages are heavy, who are billed quarterly but whose meters are read monthly.

CIVIL SERVICE COMMISSION IN CONSULTATION

The establishment of quarterly readings and the elimination of transfers of meter readings indicated immediately that we had an excess of personnel for operating requirements. It is at this point that the Civil Service Commission was called into consultation. There was the heartiest co-operation given by this Commission to the Water Works Management. It undertook a reclassification of employes who were not needed in the Water Department, and it undertook further to hold up new appointments until a careful examination could be given of the old Water Works men and the possibility of using them throughout other branches of the city service. Those were retained in the Water Works Department who had excellent efficiency ratings, with certain modifications for seniority standing. The permanent personnel thus chosen has proved itself capable and enthusiastic.

CHANGES IN MECHANICAL ARRANGEMENTS

The next step taken in our re-arrangements was to remodel the Automatic Addressograph and imprint upon our post-card bills the office records and delinquent notices as well. The Burroughs billing machines which were on the floor were revised in order to get rid of the ledger sheets and make the complete bill, accounting stub, and recapitulation sheet at one operation. This new procedure indicated that instead of the six machines that were in operation earlier, two machines could be used for part-time operation. By September 15 the first group of bills were mailed under the stub plan and on a one-cent permit.

Again we were faced with an excess of employes on general procedure. For the time being these were used to complete the transfer of the records previously spoken of. By February 1 of this year our new installation was complete and it was found that the work formerly done by 89 employes was being taken care of by 42. Because of the gradual changes in administrative procedure and the wholehearted co-operation of our Civil Service authorities during the period from July 1 to February 1, it was found possible to finish the transfer of employes and find places for all without creating new positions in the city service.

It would be possible to detail other features of our new installation, such as the electric envelope opener, the preparation of bank deposit sheets by the use of an electric check endorsing machine, and the

installation of money-changing machines and a postage-meter machine. In the application division, six copies of on-and-off orders are issued at one writing. Loose-leaf filing equipment has become standard. Meter record books are kept in fire-proof files, locked at night.

CHANGES TENDED TO IMPROVE MORALE

These illustrations of what has been done in one Water Works Department by the installation of modern mechanical devices and the co-operation of civil service authorities in re-arranging our personnel indicate very clearly, it seems to me, that it is entirely possible under merit systems now in vogue in American cities to do almost anything required for bettering the service in water works administration. By establishing proper relations with civil service authorities the personnel problem which follows the installation of such devices can be made to work itself out. What was done in Cincinnati not only did not discourage the morale of our personnel, but improved it progressively as one installation followed another. Every man in the administration knows now the purpose of the function which he performs. He knows what part he has in the general program, and how necessary he is to a satisfactory functioning of the whole office.

CONCENTRATION OF OFFICE SPACE

The new layout of our offices is also pleasing to our personnel. Formerly the offices were scattered in three units on the first floor of the City Hall. Condensing the work of our commercial unit has brought these scattered offices into one suite, and not only has it bettered the co-ordination between the executives of the division, but it has reduced the rental on floor space by almost 30 percent. The savings made possible by the installation of modern equipment and the transfer of employes is indicated by the drop in appropriations for these services in the budget of 1931. The request made for administrative services in the Department was \$62,000 less than in 1930. Furthermore, it is only fair to say that the public is pleased with the accurate and neat bills sent out, and with the quarterly method of billing. The one comment made constantly both inside the City Hall and out is: "Why did not this happen before?"

VALUABLE CO-OPERATION OF CIVIL SERVICE COMMISSION

For the purposes of this paper much credit must be given to the Cincinnati Civil Service Commission, which faced a very difficult problem and saw it through. Each man who was dropped from the Water Works roll was given a thorough examination and placed in the available position for which he showed proper qualifications. In working out this joint problem the efficiency rating system now in use in the Cincinnati service should be given its share of credit. It is called the Probst Rating System.

Water works administration faces several problems in American cities. The chief spot, however, where the Water Department comes into touch with the general public is in the field of consumers' accounting. It is there that excellent public relations can be encouraged and the public made to understand the aims and purposes of the organization. No detail is too unimportant to be given thorough consideration. In this field particularly, the most important problem for study is that of personnel. A well-trained, busy, intelligent, and courteous personnel in the commercial and consumers' division is the Water Works' first line of defense. It is here that human relations are exploited, and curiously enough, it is the last place in which our water works administrations have attempted to conform to the best practices which have been worked out in modern business.

May I suggest that at this point we modernize our personnel and mechanical processes so that these human operations shall be made to compare favorably with the great advances that have been made in the engineering practice in American water works.

GRAVEL WALL WELLS

By F. T. Quinn, Jr.[1]

The gravel wall well presents a field for elaborate presentation and discussion. This paper is limited, however, to a brief discussion of three angles, namely, (1) the need for a special well construction; (2) the construction of the gravel wall well; and (3) comparison of gravel wall well production with ordinary well production.

For wells of large capacity, the diameter varies from 10 to 38 inches, depending, of course, on the quantity of water desired and the depth of the well. If the water bearing formation consists of sand, some form of screen must be employed at the bottom of the well casing. Within this casing or screen is located the pumping unit to elevate the water to the surface.

To pump large quantities of water from a well causes the water to enter the well through the screen at an extremely high velocity. The speed of the water causes it to carry the finer sand in an amount directly proportional to the velocity. This tends to cut away the metal screen, or pack the screen openings until the flow of water is materially decreased. For this reason a well has a limiting capacity which may be safely pumped from it. The problem of raising this limiting capacity is met by an improved method of well construction —the gravel wall well.

The limiting capacity of a well may be raised in only two ways, by increasing the flow for a given velocity or decreasing the velocity for a given flow. The only way to reduce the velocity of the flow into the well without reducing the quantity is to increase the area through which the water enters or increase the circumference of the well screen itself. To increase adequately the diameter of the screen causes the cost of the well to rise to a prohibitive point so the gravel wall method of construction was devised to increase this surface with a well of ordinary diameter. This method consists in surrounding the screen with enough coarse gravel to make the outside diameter of this gravel screen about three times the diameter of the original

[1] Layne and Bowler, Inc., Memphis, Tenn.

screen. This triples the surface of the screen as the gravel is effective for screening purposes. To triple the screening surface cuts the entrance velocity of the water to one-third for the given quantity of water or triples the quantity for the same velocity of flow.

The gravel wall well is constructed as follows:

A large casing, ranging in size up to 48 or 60 inches is installed from the surface of the ground down to a depth sufficient to reach the top of the water bearing stratum. Inside of this casing is placed a casing of smaller diameter. To the bottom of this smaller casing is attached a well screen having a liberal percentage of screen openings or perforations. The well screen is installed through the water bearing stratum. As this is done, carefully selected gravel is fed around it. This gravel is inserted at the surface between the large outer casing and the small inner casing. When the screen is in place it is surrounded by a gravel wall of a diameter at least equal to the large outer casing. Temporary pumping equipment is installed in the well and pumping carried on at a sufficient rate to cause the fine sand particles to be pumped from the area surrounding the well. As this is being done additional gravel is fed from the surface between the two casings. This process is continued until the desired area of gravel filter is secured, permitting the pumping of the desired quantity of water without further removal of sand. The construction is shown in figure 1.

This substitution of gravel for sand next to the screen makes possible the use of larger screen openings cutting down still more the resistance of free flow of water into the well. It is, of course, vitally necessary to select and grade the gravel properly to give the proper screening effect.

If a well of a certain size is constructed, the static water level, where the water stands when the well is not being pumped, will be the same no matter what type of well is constructed. Water flows into the well due to a difference in head or pressure between the water in the surrounding strata and the water level in the well itself. In other words, the pumping level in a well drops below the static level just far enough so that the head or pressure is enough to force the required quantity of water into the well. Any method of lowering the resistance raises the pumping level in the well and so increases the specific capacity of the well. This is actually accomplished by the construction of the gravel wall well.

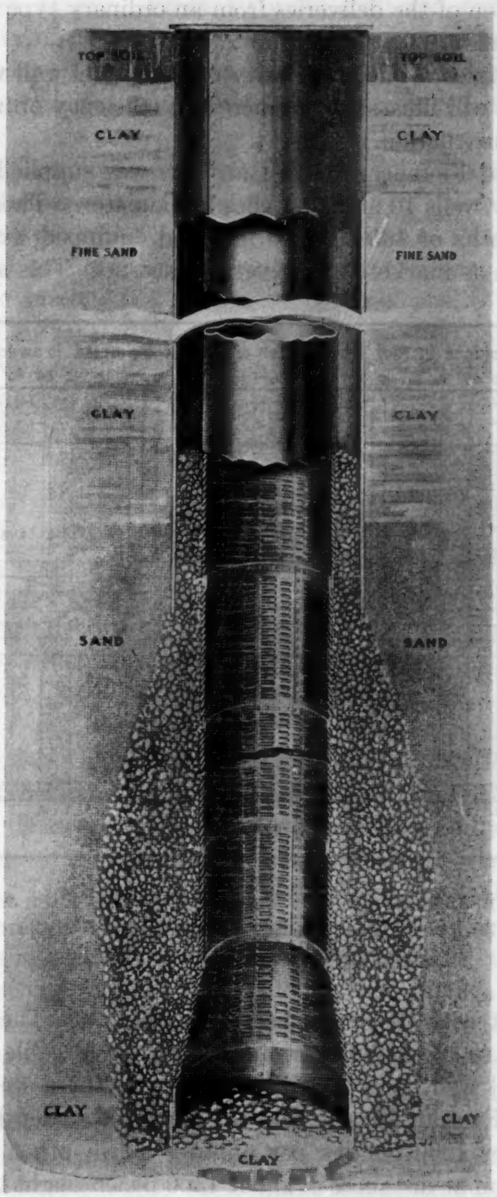

FIG. 1. TYPICAL SECTION SHOWING GRAVEL WALL WELL

A comparison of the deliveries from an ordinary type well and the gravel wall well is shown in figure 2.

A few examples of the superiority of the gravel wall well over the old type well will illustrate the increased efficiency obtained by the use of this construction.

The City of Florence, South Carolina, was supplied with water from ordinary wells 10 and 12 inches in diameter. These wells were drilled to depths of 300 to 1000 feet and equipped with a type of slotted screen as marketed by several concerns. This screen was in

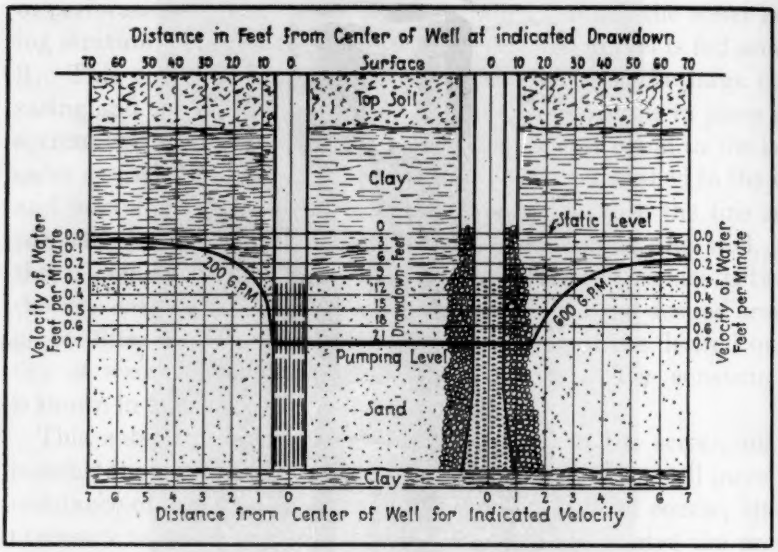

FIG. 2. A DIRECT COMPARISON. TWO DEEP WELLS EACH WITH 12-INCH SCREEN, 30 FEET LONG AND SET IN THE SAME FORMATION WITH 40 PERCENT VOIDS IN SAND AND GRAVEL

direct contact with the water bearing formation. These wells supplied from 75 to 125 gallons per minute with considerable sand trouble. A gravel wall well, located within 20 feet of these wells, equipped with 8 inch Everdur Bronze Shutter Screen at a depth of 730 feet produced over 1200 gallons per minute. Two other wells in the same formation at distances of about 1500 feet brought the combined capacity to more than 3000 gallons per minute.

At the Camden, N. J., plant of the Victor Talking Machine Company a great many wells were drilled in an attempt to secure an

adequate water supply. From 10 wells scattered over as many acres a quantity of only 1200 gallons per minute was secured. Finally the gravel wall type well was installed and one well produced 2400 gallons per minute, twice as much as the combined output of ten ordinary wells.

The City of Kinston, N. C., employed the ordinary type wells of 8- and 10-inch diameter. The average capacity of these wells was about 75 gallons per minute each. In the midst of these wells was placed a gravel wall well with 13-inch shutter screen. This well produced approximately 900 gallons per minute.

The Illinois Central Railroad at Paxton, Ill., secured its water from two ordinary wells, 10-inch in diameter, which produced only 40 to 50 gallons per minute each. Two wells of the gravel wall type were constructed, each having a production of approximately 400 gallons per minute.

At Edenton, N. C., the old well in use produced only 75 to 80 gallons per minute. A gravel wall well through the same strata brought the production to 800 gallons per minute.

These citations, actual examples of the use of the gravel wall well, indicate its superiority over the ordinary well, when proper methods are employed by skilled operatives in its construction.

DISCUSSION

L. A. Smith:[2] Mr. Quinn is to be commended for his brief and clear presentation of the advantages of gravel wall wells and the method of constructing them, which is a very ingenious one and so simple in application that with ordinary care good results are comparatively easy to obtain. The only comment which I have to make is based upon local experiences at Madison.

Several years ago a well was developed in Madison that had a capacity of nearly 4 m.g.d. This well was drilled in a sandstone formation which was rather loose in nature. In view of the fact that this is a rather large amount of water to pump from a single hole a gravel wall well was used, as it was felt that the quantity of sand which would be obtained would be materially reduced. We found that this was a fact by comparison with the quantity of sand that we obtained from other wells. The proportion of sand in the water pumped from this well was only 0.01 percent, which seems, at first

[2] Superintendent, Water Department, Madison, Wisc.

glance, to be a negligible amount. However, this would amount to 300 gallons, or $1\frac{1}{2}$ cubic yards of sand per day. In a year's time over twenty carloads of sand would be pumped into the distribution system. The fine sand which flows into a well when the velocity is high not only tends to clog the screen and to cause excessive wear upon the pump impellors, but also causes serious damage in the distribution system. Faucet packings, toilet valves and water softeners are adversely effected, and in some cases the carrying capacity of the mains is seriously reduced by sand deposits.

Because of these facts, this well has only been used as an emergency unit since its installation, but the demand for water in Madison has now reached the point where this well must be used regularly during the summer months. In order to prevent sand going into the distribution system, plans have been made to provide a baffle chamber and settling basin at the surface of the ground, and to pump the water twice. The deep well pump which is now installed will be used to pump the water to the surface of the ground and after the sand has been removed it will be pumped into the distribution system with a horizontal centrifugal pump. The only other alternative which we had if we were to use this well continuously was to reduce the rate of pumping to a point which would lower the velocity of flow into the well below the velocity required to carry sand. It was found, experimentally, that the pumping rate would have to be reduced from 4 to 3 m.g.d., which, of course, would increase our fixed charges one-third, and would also render this well much less valuable to us because of the lowered capacity.

I have outlined the above condition not to criticize gravel wall wells, but to emphasize two statements which Mr. Quinn makes, first, that, if the maximum benefit is to be obtained with this type of well it is vitally necessary to select and grade the gravel properly to give the proper screening effect, and, second, that, while the amount which can safely be pumped from a well without producing sand is materially increased, there is still a limit in the pumping rate if water without sand is to be obtained. The increasing of the specific capacity of a well by lowering the velocity of flow into it is a very important point, and I agree that this can actually be accomplished to a limited extent by the construction of a gravel wall well.

I recognize that gravel wall wells are ordinarily used in loose formations, and I feel that they are the best type under these conditions, and, if properly installed, undoubtedly increase the capacity of the

well and decrease the head against which the water is to be pumped. I feel that, in spite of our experience in Madison, gravel wall wells can be used in many instances in obtaining water from rock formations if the sandstone particles are well cemented together, but the distinct field where gravel wall wells can be used to advantage is in sand and gravel formations where maximum capacity is desired without sand.

CHAIRMAN CHESTER: What is the life of your well in coarse sand and gravel?

JAMES SHEAHAN:[3] We have not constructed any gravel wall wells. We erected a new plant about ten years ago and we put all new wells in it and abandoned all of the old wells we had in our old system, which were all in good shape at that time. At our new plant we put in twenty-one new wells in 1922 and 1923. We have been using them since and have not had to replace any of them and the supply is as good now as it was at the time they were made. We use a very fine screen, or strainer, which does not allow sand to flow into our wells and are very particular after a long service to watch closely and if we do find a little sand coming, we work on the well and cure it. We had one system of wells that depreciated very quickly, especially after the fourth year. They were what we called our gravity flow wells. They flowed into a tunnel under the ground about 90 feet below the surface and the water was pumped from there by high-pressure pumps to the mains.

CHAIRMAN CHESTER: What do your wells die of when they expire?

MR. SHEAHAN:[3] Since we have been using air, or pumps, we have never had a well to stop giving the amount of water that we need. The depreciation has been very small and we figure the life of them safely at ten years. That is our estimate, but we have been using some wells more than twenty years with a power system and have never lost a well. However, with the gravity flow we lost many in different ways, some by the water on the outside eating through the threads in the couplings and entering the well in that way; others by holes rusting through the pipe; sometimes the strainers would get

[3] General Superintendent, Water Department, Memphis, Tenn.

sealed off by a formation of scale around them; others by sand cutting through the slots, allowing sand to enter the well where we could not stop them without losing the well.

Wm. W. Brush:[4] Our gravel wells are still in swaddling clothes age. There are, however, quite a large number of gravel wells that have been put down on the Western part of Long Island, for various private water companies that operate within the limits of the City of New York, and for some private municipalities operating just outside of the City of New York. I should say they were perhaps ten years old. The wells have been very satisfactory generally. Our own wells are of the gravel wall type and they are seven in number. They yield approximately a maximum of about 1600 and a minimum of 800 gallons a minute.

We believe that the gravel wall type well is the type best suited for the conditions on Long Island, where we have generally a fairly coarse sand, or gravel, although occasionally we have a relatively fine sand. One well of the gravel type was not successful, due to the fact that there were a large number of clay balls in the water bearing strata and the rate of flow past these clay balls was high enough to bring the clay into suspension and carry it to the well. For that particular type of formation a smaller well, with a much smaller capacity, would undoubtedly be the type that should be used, and we do not expect to have any gravel wells sunk into that particular formation. But that is an unusual type of formation for us to have.

I see no reason at all why a gravel type well should not have as long, and generally speaking, a longer life than the usual strainer type well without being surrounded by gravel. We have wells which are operated by suction that are some twenty years old, and they are operating very well today, practically the same as when we started.

Mr. Lanham: They are not graveled?

Mr. Brush: No, they are not. On the other hand, if we had had graveled wells in that same location I would be surprised if they were not operating just as well at the end of that period. We have many wells of all kinds and our conclusions are that in our particular situation the graveled type well is generally better suited to give us the

[4] Chief Engineer, Department of Water Supply, Gas and Electricity, New York, N. Y.

quantity of water that we need, and we believe at a low price. The private companies certainly have found them to be the most efficient for their operations within limits of the City of New York.

Mr. Lanham: Do you know of any cases where the sand clogs with the gravel and cuts off the supply?

Mr. Brush: I think that has occurred in one or two instances. I should think it would occur if you do not have your balance, or if you do not have your velocity of flow at the outside periphery of your gravel bulb, or wall, low enough to be below the velocity at which sand will be moved. If the sand is carried into the gravel you will have to get it out by agitation and pumping at a relatively high rate, and practically reconditioning the well. That, however, should not be very difficult or expensive.

Mr. Lanham: What I am most interested in learning is the difficulty we have had with gravel wall wells. We never had any in Memphis.

Mr. Brush: The gravel wall wells have been a real success on Long Island. The private companies have altogether at the present time somewhere around forty, or fifty, of these wells and they are giving satisfactory results. They are operated automatically in some instances, thrown in and out depending on pressure. Usually they are started up by an attendant. But they have been successful and are being added to from time to time as the private companies need additional supplies. Therefore, I can say without question that these wells in our type of formation are successful and satisfactory.

Chairman Chester: Do you have any iron in your water and sand?

Mr. Brush: Unfortunately, yes. We have two wells that we cannot operate satisfactorily on account of iron and we are putting in a filter plant. I believe, however, that the iron will not make any difference in the life of the wells, because we have had numerous wells where we have iron, without serious clogging

We will have to throw the iron out of solution into suspension and filter it out before we can obtain satisfactory water from these two

wells. Our work is done by contract and we do not place upon the contractor any responsibility for the quality of the water, except as to the sanitary quality as affected by his operations, but other than that the city takes the full responsibility for the quality of the water, because the contractor has no control over that.

Chairman Chester: Does the iron ever stop up your gravel?

Mr. Brush: We have never had any indication that there has been any serious stoppage of the gravel by the iron in the water. The iron is an iron that will come out from solution into suspension, if the water is allowed to stand for several hours. Of course, in hot water it comes out very promptly, but the water without iron removal is hopeless as a supply when it goes through the heating system.

Samuel B. Morris:[5] I hesitate to speak on this subject because of the formidable discussion presented after the paper was presented. For example, I would hesitate to say that a slow sand filter is superior to a rapid sand filter as a general statement. Each problem requires its own solution. There are so many different classifications of underground materials in which wells are developed that it is impossible to designate any one best method. In fact, the gravel well as we have it out West is develcped somewhat differently from the gravel wells described in the paper under discussion.

In Southern California the gravel envelope well is put down by having a well shoe which is a foot, or so, larger in diameter than the casing, itself, and thus the shoe cuts all of the strata to a larger dimension and permits the feeding of gravel about the casting as it is put down. When the well is put down to its final depth, the log having been kept of the materials which it has passed through, the well casing is then perforated with a knife, or other equipment. There are also a lot of wells put down by rotary means, in which it is sunk by the customary rotary process, using mud to hold off the gravel until the well is down. Then well casing perforated at the proper locations for the water strata is lowered into place. As they start to pump from the well they feed gravel in as the clay is pumped out.

We have a number of wells somewhat akin to the description of the gravel well here. We sink a concrete shaft generally down to

[5] Chief Engineer, Water Department, Pasadena, Calif.

water level. Our water level in the average is 250 to 300 feet below the surface of the ground, and in order to insure a straight well we sink a concrete pit first to water level, and we drill from there down. During the drilling process we feed gravel at the bottom of this pit, so that no cavities are created in the drilling of the well. A well about a thousand feet in depth will generally take about 200 yards of gravel during the drilling. Our wells are rather large wells for that depth. They are generally 26-inches in diameter and one of them is 1220 feet in depth.

The regions that demand the gravel envelope method are those that have the finest sand. We do not happen to have much of that type in our area, but there are many communities in California where they do, and where the gravel envelope enables them to have a much larger production from the quicksand type of formation. Just to indicate how different the drilling methods may be in different conditions I would like to mention the conditions in Fresno, California. There they drill the wells to the top of a very hard clay stratum, perhaps two or three hundred feet below the surface. They end their casing there and then drill down through clay into the fine sand below it. Then they install a pump of about twice the normal pumping capacity on the well and pump several carloads of sand out of the well. When the sand ceases to flow they put on a pump at about the normal capacity, about half the test flow of the well, and have no difficulty whatsoever with sand from then on. All the water is taken from the bottom of the well, and the well is not perforated at all.

So in each community, with widely varying conditions, they should devise the most successful means of meeting their own problems. This is particularly true of well drilling methods.

LLOYD M. REBSAMEN:[6] I will talk about our experience in Arkansas with gravel walled wells. It might interest you to know that on a recent well contract the contractor positively guaranteed to furnish a gravel walled well which would not pump sand in objectionable amount for a period of two years and our company is to be the judge of objectionable amounts of sand pumped, a most unusual contract.

Our practice during the last twenty years has been to use a wire wrapped screen

[6] Jonesboro, Ark.

We have a stratum of water bearing sand as close to the surface as forty feet, but it has been our practice to wall off this stratum and tap another one lying mostly below 120 feet. Our practice has been to bore a 30-inch hole for a 26-inch pit and to use a 12-inch screen of between 20 and 40 feet in length, the screen to lie, of course, in the water stratum. These wells are bored and the walls mudded in. After the casing has been sunk gravel is packed around the casing making in fact a gravelled wall well.

One of these wells is producing 1100 gallons per minute. The well has forty feet of wire wrapped screen, is eleven years old and has given absolutely no sand pumpage in that time.

Mr. Lanham: Is that well in a sand or a sand gravel stratum?

Mr. Rebsamen: It is in sand, running in size from a medium coarse to almost as fine as quick sand. It seems that the gravel packing of the wells has prevented even the finer sand from coming through the screen.

Up to the present time we have not been entirely sold on the use of the shutter screen, but this new well will have the shutter type screen. We hope that our experience with this type will be as satisfactory as with the wire wrapped type of screen. It is on this new well with the shutter type screen that the guarantee of no objectionable sand pumpage for two years has been made, I think this is a most unusual contract, for we are to be the judge of objectionable sand pumpage and I think this speaks very well for this type of screen.

D. D. Gross:[7] In Denver formerly a large percentage of the water was taken from underground galleries. These have been largely abandoned for open streams. The first underground galleries were constructed in 1882–84. The underground galleries were of crib construction and worked well. A couple of years later another series of galleries were constructed in the sand with very fine grains. These wells filled up in about three years to the extent that it was necessary to reconstruct them.

The reconstructed galleries were placed about eighteen feet below the surface of the bed of the stream and they were constructed of

[7] Board of Water Commissioners, Denver, Colo.

concrete pipe, laid with open joints, and heavily packed with gravel. After they were in use for a few years the quantity of water obtained was reduced from 8 to 5 or 6 million gallons per day. Those galleries were first constructed in 1886. They were reconstructed about 1889 and are in use at the present time.

It would seem to me that the filling in of sand into the gallery or well under a given type of construction would be dependent on the size of the sand grains and the velocity of the water. The operator can regulate the velocity of inflow by the amount of draw down permitted in the well or gallery.

DEVELOPMENTS IN ELEVATED TANKS FOR DISTRIBUTION SYSTEMS

By J. O. Jackson[1]

The function of storage in distribution systems has been analyzed and described in excellent papers by Edmond K. Barnum[2] and by Nicholas S. Hill.[3]

In a water works system without stored reserve it is necessary to provide supply, pumping and distribution facilities each with a capacity at least equal to the maximum or peak demand. The introduction of stored reserve of the proper amount permits of a reduction in the size and, therefore, in the original cost, fixed charges and operating costs of these supply, pumping and distribution facilities. This is possible because the demand during the peak hour of the day of maximum consumption is very much higher than the average hourly demand over longer peak periods of the same day.

Advantages resulting from the introduction of a proper amount of storage are: (1) reduced capital outlay and annual charges because of lowered peak capacities, (2) better pressure characteristics in certain districts, (3) a more dependable water reserve for fire purposes and (4) economies resulting from part-time operation of certain pumping facilities.

As an example of a typical determination of the economical amount of storage reserve, assume a city whose average annual rate of consumption, corrected for population change, is 10,000,000 gallons per twenty-four hours. The amount of water consumed for each hour of the maximum and average summer and winter days is shown in table 1. Figure 1 is a graph of the hourly water consumption for the maximum summer day.

Table 2 was prepared from table 1 showing a method of calculating the proper tank capacity for any peak period. The pump and tank capacities should be based on the day of maximum consumption in

[1] Chief Engineer, Pittsburgh—Des Moines Steel Company, Pittsburgh, Pa.

[2] Journal, February, 1926, p. 109.

[3] Journal, November, 1926, page 593.

order that the system will satisfy the consumption requirements during maximum demand.

It is apparent that for any given peak period in hours, storage must

TABLE 1

Record of water consumption based on average annual rate of ten million gallons per twenty-four hours

PERIOD OF DAY	WATER CONSUMPTION IN GALLONS			
	Summer conditions		Winter conditions	
	Maximum day	Average day	Maximum day	Average day
12- 1 a.m.	314,000	273,000	261,000	227,000
1- 2	314,000	273,000	261,000	227,000
2- 3	314,000	273,000	261,000	227,000
3- 4	230,000	200,000	261,000	227,000
4- 5	292,000	254,000	209,000	182,000
5- 6	419,000	364,000	314,000	273,000
6- 7	627,000	545,000	419,000	364,000
7- 8	627,000	545,000	450,000	391,000
8- 9	627,000	545,000	470,000	409,000
9-10	836,000	727,000	419,000	364,000
10-11	575,000	500,000	366,000	318,000
11-12	575,000	500,000	419,000	364,000
12- 1 p.m.	522,000	454,000	366,000	318,000
1- 2	627,000	545,000	419,000	364,000
2- 3	522,000	454,000	314,000	273,000
3- 4	627,000	545,000	366,000	318,000
4- 5	731,000	636,000	366,000	318,000
5- 6	1,464,000	1,273,000	314,000	273,000
6- 7	1,255,000	1,091,000	419,000	364,000
7- 8	1,359,000	1,182,000	314,000	273,000
8- 9	522,000	454,000	366,000	318,000
9-10	522,000	454,000	366,000	318,000
10-11	314,000	273,000	314,000	273,000
11-12	419,000	364,000	314,000	273,000

be provided equal to the difference between accumulated pumping at the average rate and accumulated consumption during the peak period. It is also apparent that for any given maximum pumping

rate there is only one quantity of storage reserve which will just fulfill the consumption requirement for that rate. Table 3 is a tabulation prepared from a number of calculations similar to those of table 2 of all of the proper combinations of pump and tank capacities for peak periods from one to twenty-four hours.

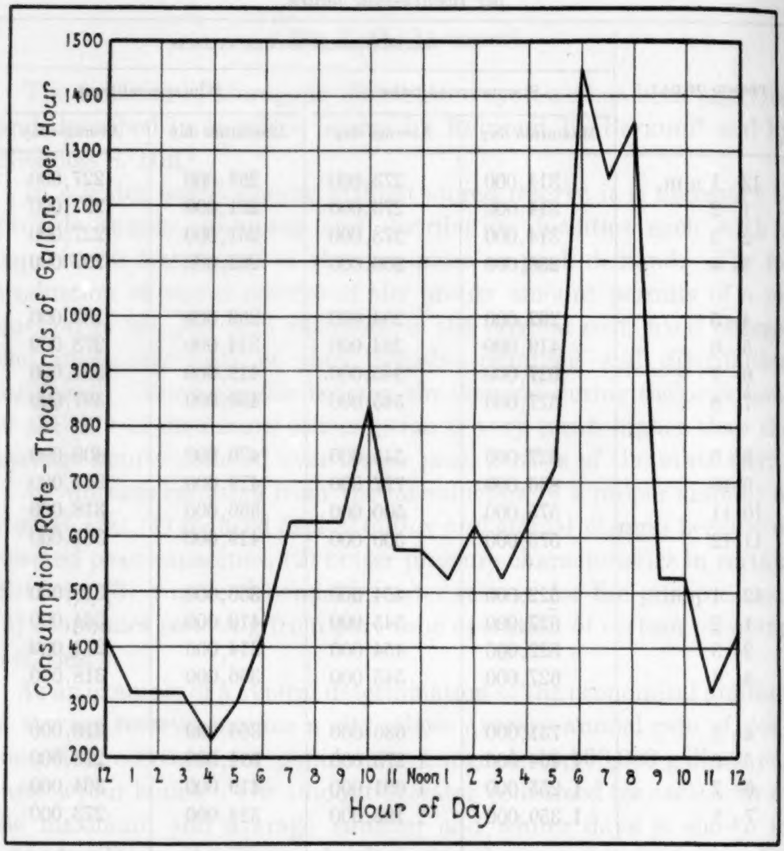

FIG. 1. WATER CONSUMPTION IN THOUSANDS OF GALLONS PER HOUR FOR MAXIMUM SUMMER DAY

The particular combination of pump and tank capacity having the lowest annual cost may then be determined by calculating the annual cost of several periods and selecting the one having the minimum.

An illustration of such calculations is given in table 4. In order that the results will be representative of the complete yearly cycle,

the calculations should be based on the average yearly rate and not on the maximum rate. If the average winter consumption characteristics are quite different from the summer characteristics, the

TABLE 2

Method of calculating tank capacity required for various peak periods

A. HOURLY CONSUMPTION	B. ACCUMULATED CONSUMPTION	C. ACCUMULATED PUMPING	D. ACCUMULATED DIFFERENCE COL. C.–COL. B.
Six-hour period, 3 p.m. to 9 p.m.; average pumping rate, 993,000 gallons per hour			
627,000	627,000	993,000	+366,000
731,000	1,358,000	1,986,000	+628,000 (1)
1,464,000	2,822,000	2,979,000	+157,000
1,255,000	4,077,000	3,972,000	−105,000
1,359,000	5,436,000	4,965,000	−471,000 (2)
522,000	5,958,000	5,958,000	0

Required tank capacity for six-hour period equals maximum positive (1) plus the maximum negative figure (2) column D or 628,000 + 471,000 or 1,099,000 gallons.

A. HOURLY CONSUMPTION	B. ACCUMULATED CONSUMPTION	C. ACCUMULATED PUMPING	D. ACCUMULATED DIFFERENCE COL. C.–COL. B.
Nine-hour period, 11 a.m. to 8 p.m.; average pumping rate, 854,000 gallons per hour			
575,000	575,000	854,000	+279,000
522,000	1,097,000	1,708,000	+611,000
627,000	1,724,000	2,562,000	+838,000
522,000	2,246,000	3,416,000	+1,170,000
627,000	2,873,000	4,270,000	+1,397,000
731,000	3,604,000	5,124,000	+1,520,000 (3)
1,464,000	5,068,000	5,978,000	+910,000
1,255,000	6,323,000	6,832,000	+509,000
1,359,000	7,682,000	7,686,000	0

Required tank capacity for nine-hour period is maximum positive number (since there are no minus numbers) in column D or (3) or 1,520,000 gallons.

calculations should be made for summer and winter conditions independently and these results combined to form a yearly average. In making the calculations, it is necessary to determine the annual cost for each portion of the supply and distribution system from the

original cost, the estimated life in years and the salvage value. To facilitate these calculations table 5 has been prepared which gives the annual cost in percent of original cost for various life terms in years

TABLE 3

Pumping and storage rates for various peak periods based on maximum summer day

PERIOD		TOTAL CONSUMPTION	AVERAGE HOURLY CONSUMPTION (MAXIMUM PUMPING RATE)	REQUIRED STORED RESERVE
Hours	Time			
		gallons	*gallons*	*gallons*
1	5 p.m.– 6 p.m.	1,464,000	1,464,000	None
2	5 p.m.– 7 p.m.	2,719,000	1,359,000	105,000
3	5 p.m.– 8 p.m.	4,078,000	1,359,000	105,000
4	4 p.m.– 8 p.m.	4,809,000	1,202,000	471,000
5	3 p.m.– 8 p.m.	5,436,000	1,087,000	816,000
6	2 p.m.– 8 p.m.	5,958,000	993,000	1,099,000
7	1 p.m.– 8 p.m.	6,585,000	941,000	1,257,000
8	12 a.m.– 8 p.m.	7,107,000	888,000	1,414,000
9	11 a.m.– 8 p.m.	7,682,000	854,000	1,520,000
10	10 a.m.– 8 p.m.	8,257,000	826,000	1,603,000
11	9 a.m.– 8 p.m.	9,093,000	827,000	1,610,000
12	8 a.m.– 8 p.m.	9,720,000	810,000	1,648,000
13	7 a.m.– 8 p.m.	10,347,000	796,000	1,691,000
14	6 a.m.– 8 p.m.	10,974,000	784,000	1,728,000
15	6 a.m.– 9 p.m.	11,496,000	766,000	1,780,000
16	6 a.m.–10 p.m.	12,018,000	751,000	1,825,000
17	5 a.m.–10 p.m.	12,437,000	732,000	1,882,000
18	5 a.m.–11 p.m.	12,751,000	708,000	1,977,000
19	5 a.m.–12 p.m.	13,170,000	693,000	2,037,000
20	5 a.m.– 1 a.m.	13,484,000	674,000	2,113,000
21	5 a.m.– 2 a.m.	13,798,000	657,000	2,181,000
22	5 a.m.– 3 a.m.	14,112,000	642,000	2,241,000
23	4 a.m.– 3 a.m.	14,404,000	626,000	2,306,000
24	12 p.m.–12 p.m.	14,634,000	610,000	2,440,000

and for various salvage values also expressed in percent of original cost.

To make clear the basis and proper use of the table, the following example and proof is offered:

Assume: Original Cost, $10,000.00.
Life, 5 years.
Interest Rate, 6 percent compounded annually.
Salvage Value, 20 percent net.

Annual Cost (from table) 20.19 percent × $10,000 = $2019 per year.

Proof of Sufficiency:

Assume bond issue at beginning of life term in principal amount of $10,000.00 at 6 percent interest rate or $600.00 per year.

Above annual cost of $2019.00 will pay interest on bonds of $600.00 and leave $2019.00 − 600.00 = $1419.00 annual sinking fund to amortize bonded indebtedness.

Sinking fund accumulation:

	Annual payment	*Interest term*	*Compound amount*
At end of 1st year..........	$1419.00	4 yrs. @ 6%	$1791.46
At end of 2nd year..........	1419.00	3 yrs. @ 6%	1690.06
At end of 3rd year..........	1419.00	2 yrs. @ 6%	1594.39
At end of 4th year..........	1419.00	1 yr. @ 6%	1504.14
At end of 5th year..........	1419.00	none	1419.00
Total..........			$7999.05
Salvage Value..........			2000.00
Total (sinking fund accumulation plus salvage)..........			$9999.05(A)

TABLE 4

Annual cost of supply and distribution system

Average daily consumption, 10,000,000 gallons per twenty-four hours.

Pump capacity, 854,000 gallons per hour.

Storage capacity, 1,520,000 gallons; fire reserve, 500,000 gallons; total tank capacity, 2,020,000 gallons.

DESCRIPTION	ORIGINAL COST	LIFE IN YEARS	SALVAGE VALUE	ANNUAL CHARGE	ANNUAL COST
			per cent	*per cent*	
Wells..........	$50,000	30	10	7.14	$3,560
Filters..........	248,000	25	10	7.64	19,000
Pumping stations..........	198,600	20	20	8.17	16,200
Power..........	x				135,500
Mains..........	2,085,300	40	10	6.58	137,200
Storage reservoir..........	200,500	30	20	7.01	14,055
Maintenance..........	x				75,660
Labor and overhead..........	x				54,080
Total..........	$2,782,400				$455,255

TABLE 5

Table of sinking fund rates to provide for amortization and depreciation

Following is a tabulation of sinking fund rates expressed as percentages of original cost which will provide for interest charges at six percent per annum and will accumulate during the indicated life period, the original cost less the net salvage value. The net salvage value is also expressed as a percent of the original cost.

LIFE IN YEARS	SINKING FUND RATES IN PERCENT OF ORIGINAL COST AT 6 PERCENT COMPOUNDED ANNUALLY BASED ON FOLLOWING NET SALVAGE VALUES IN PERCENT OF ORIGINAL COST							
	No salvage	5 percent salvage	10 percent salvage	15 percent salvage	20 percent salvage	25 percent salvage	50 percent salvage	75 percent salvage
1	106.00%	101.00%	96.00%	91.00%	86.00%	81.00%	56.00%	31.00%
2	54.54	52.11	49.69	47.26	44.83	42.40	30.27	18.13
3	37.41	35.84	34.27	32.70	31.13	29.56	21.70	13.85
4	28.86	27.22	26.57	25.43	24.29	23.15	15.37	11.72
5	23.74	22.85	21.97	21.08	20.19	19.30	14.87	10.43
6	20.34	19.62	18.91	18.19	17.47	16.76	13.17	9.59
7	17.91	17.31	16.72	16.12	15.53	14.93	11.95	8.98
8	16.10	15.59	15.09	14.58	14.08	13.57	11.05	8.52
9	14.70	14.26	13.83	13.39	12.96	12.52	10.35	8.17
10	13.59	13.21	12.83	12.45	12.07	11.69	9.80	7.90
11	12.68	12.35	12.01	11.68	11.34	11.01	9.34	7.67
12	11.93	11.64	11.34	11.04	10.75	10.45	8.97	7.48
13	11.30	11.04	10.77	10.51	10.24	9.98	8.65	7.33
14	10.76	10.52	10.29	10.05	9.81	9.57	8.38	7.19
15	10.30	10.08	9.87	9.65	9.44	9.22	8.15	7.07
16	9.89	9.70	9.51	9.31	9.12	8.92	7.95	6.97
17	9.54	9.37	9.19	9.01	8.83	8.66	7.77	6.89
18	9.24	9.08	8.91	8.75	8.59	8.43	7.62	6.81
19	8.96	8.81	8.66	8.51	8.36	8.22	7.48	6.74
20	8.72	8.58	8.45	8.31	8.17	8.04	7.36	6.68
21	8.50	8.37	8.25	8.12	8.00	7.87	7.25	6.62
22	8.30	8.18	8.07	7.95	7.84	7.72	7.15	6.57
23	8.13	8.02	7.91	7.81	7.70	7.59	7.06	6.53
24	7.97	7.87	7.77	7.67	7.57	7.47	6.98	6.49
25	7.82	7.73	7.64	7.55	7.46	7.37	6.91	6.46
26	7.69	7.60	7.52	7.43	7.35	7.27	6.84	6.42
27	7.57	7.49	7.41	7.34	7.26	7.18	6.79	6.39
28	7.46	7.39	7.32	7.24	7.17	7.10	6.73	6.37
29	7.36	7.29	7.22	7.16	7.09	7.02	6.68	6.34
30	7.27	7.20	7.14	7.08	7.01	6.95	6.63	6.32
40	6.65	6.61	6.58	6.55	6.52	6.49	6.32	6.16
50	6.34	6.33	6.31	6.29	6.28	6.26	6.17	6.09
60	6.19	6.18	6.17	6.16	6.15	6.14	6.09	6.05
70	6.10	6.10	6.09	6.09	6.08	6.08	6.05	6.03
80	6.06	6.05	6.05	6.05	6.05	6.04	6.03	6.01
90	6.03	6.03	6.03	6.03	6.02	6.02	6.01	6.01
100	6.02	6.01	6.01	6.01	6.01	6.01	6.01	6.00

Note: When salvage value = 100 percent of original cost—sinking fund rate = 6 percent.

TABLE 5—*Concluded*

Formula: The above table is based upon the following:

$$A = \frac{i\,[(1+i)^n - s]}{(1+i)^n - 1}$$

Where a = Annuity in percent of original cost (cents per dollar of original cost)
i = Interest rate compounded annually (table based on 6 percent)
n = Life in years = term of annuity
s = Net salvage value = salvage value less cost of salvaging

Example of calculation for table:

Assume i = 6 percent, n = 10 years, s = 10 percent

$$A = \frac{i[(1+i)^n - s]}{(1+i)^n - 1} = \frac{.06[(1.06)^{10} - .10]}{(1.06)^{10} - 1} = \frac{.06(1.79 - .10)}{1.79 - 1} = .1283 = 12.83 \text{ percent}$$

Example of use of table:

Find annual cost of tank and tower—original cost $10,000.00—life of structure thirty years
Annual maintenance cost $85.00 and net salvage value 25 percent
Sinking fund providing for amortization and depreciation (from table)

For thirty years and 25 percent salvage 6.95 percent × $10,000	=	$695.00
Annual maintenance (painting, etc.) estimated	=	85.00
Total annual cost	=	$780.00

Since the annual cost is sufficient to pay annual interest charges on the bond issue and to accumulate through the sinking fund an amount which, with the salvage revenue, is sufficient[4] to retire the bond issue, the annual cost represents the total annual expense resulting from the expenditure.

After the economical combination of pump and storage capacity has been determined, the hourly consumption rate and the cumulative consumption may be charted as in figures 2 and 3, and pumping programs developed. Figure 3 for the average summer day indicates that the pumps are to be operated at maximum capacity of 854,000 gallons per hour only from about 3.40 p.m. to 9.15 p.m. and for the remainder of the twenty-four hours the rate may be reduced to 427,000 gallons per hour, the storage reservoir becoming filled at about six in the morning. In the maximum summer day the pumps would operate at full capacity for a period of nine hours instead of about

[4] The error of 95 cents is due to annual cost percentage being carried only to second decimal place.

six. For days other than the average or maximum, the pumps would operate at maximum capacity for a sufficient period to provide for

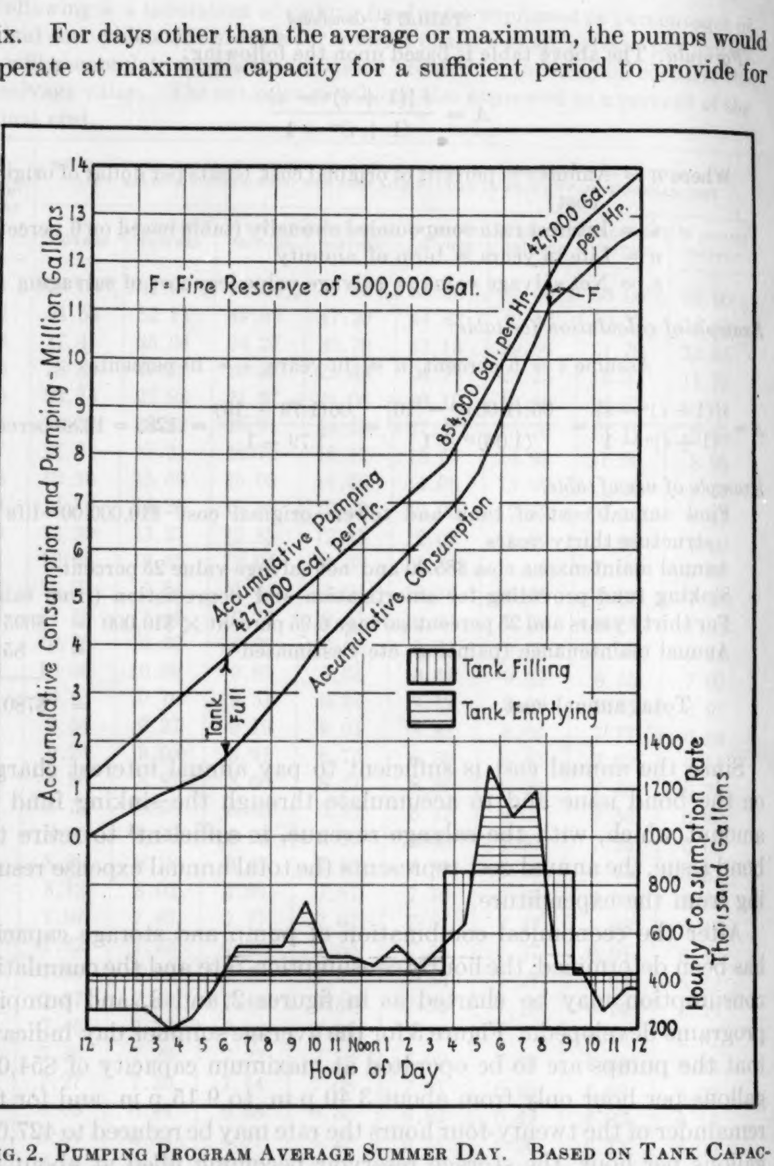

FIG. 2. PUMPING PROGRAM AVERAGE SUMMER DAY. BASED ON TANK CAPACITY OF 2,020,000 GALLONS, INCLUDING FIRE RESERVE OF 500,000 GALLONS

the actual consumption. During the average winter day pumps operating at 416,000 gallons per hour from six fifteen until midnight are sufficient and the entire plant may be shut down for the remainder

of the day. A further elaboration of these programs, in order to make the example complete, would only involve repetition and since each problem will have many special conditions, no benefit would result.

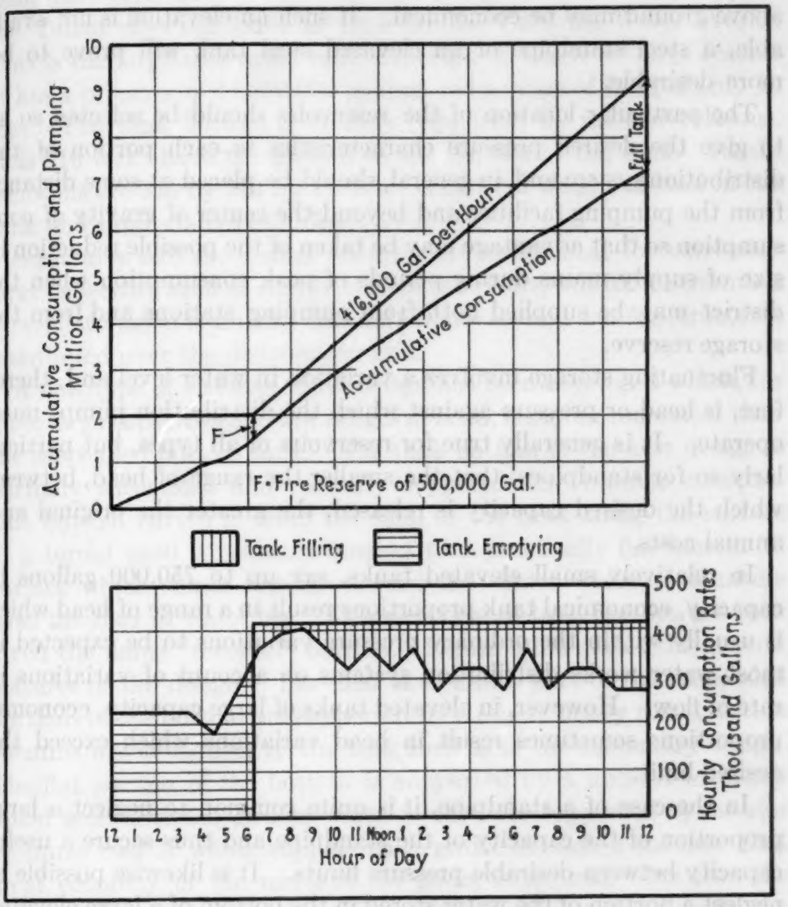

FIG. 3. PUMPING PROGRAM AVERAGE WINTER DAY. BASED ON TANK CAPACITY OF 2,020,000 GALLONS, INCLUDING FIRE RESERVE OF 500,000 GALLONS

It should not be assumed from this example that storage for a peak period of nine hours will be the economical amount. The proper storage will vary from a few hours to several days depending upon the particular conditions encountered, the type of supply and the capacity and condition of existing supply and distribution facilities.

After the economical capacity of the storage system has been determined, the particular type of storage will be indicated by the general contour of the ground in the vicinity of the desired location of the reservoir. If it may be located on a nearby elevation, a concrete reservoir underground or perhaps a large steel reservoir above ground may be economical. If such an elevation is not available, a steel standpipe or an elevated steel tank will prove to be more desirable.

The particular location of the reservoirs should be selected so as to give the desired pressure characteristics to each portion of the distribution system and, in general, should be placed at some distance from the pumping facilities and beyond the center of gravity of consumption so that advantage may be taken of the possible reduction in size of supply mains during periods of peak consumption when the district may be supplied both from pumping stations and from the storage reserve.

Fluctuating storage involves a variation in water level and, therefore, is head or pressure against which the distribution pumps must operate. It is generally true for reservoirs of all types, but particularly so for standpipes, that the smaller the range of head, between which the desired capacity is released, the greater the original and annual costs.

In relatively small elevated tanks, say up to 750,000 gallons in capacity, economical tank proportions result in a range of head which is usually within the ordinary pressure variations to be expected in most water works distribution systems on account of variations in rate of flow. However, in elevated tanks of large capacity, economic proportions sometimes result in head variations which exceed the desired limit.

In the case of a standpipe, it is quite common to neglect a large proportion of the capacity of the standpipe and thus secure a useful capacity between desirable pressure limits. It is likewise possible to neglect a portion of the water stored in the bottom of a large elevated tank and thus more economically secure the desired active storage between permissible ranges of pressure. This has the advantage that the volume of water neglected is available at slightly lower pressures in case of unusual demand resulting from fire or other emergencies.

There are cases, however, in present highly developed water works distribution systems where pressure and pumping characteristics

have been so carefully determined and regulated that storage tanks with relatively low ranges of head are desirable and economical even at an increased cost.

Several elevated tanks of large capacity and very low range of head have been built. One very interesting structure of this type is the Tallah reservoir built in 1911 for the Calcutta Water Works. This is the largest elevated tank structure of which we have record. It has a capacity of 11,250,000 gallons and a range of head of only 16 feet. The tank bottom is entirely supported by interior columns. It is 110 feet above the ground to the bottom of the tank. Its dimensions are 320 by 320 by 16 feet. The total weight of steel in the tank and supports is 4480 tons.

Structures like the Tallah reservoir are economical for extremely large capacities such as supply system reservoirs, but for distribution system storage it is usually desirable to use several smaller structures distributed over the distribution grid.

A new type of elevated tank design has been developed which, for quite large capacities and low ranges of head, is more economical than the suspended bottom tank. The tank bottom of the new design is partially suspended and partially supported by interior columns. The bottom curves in from the shell of the tank along the surface of a toroid until it becomes tangent to a practically flat horizontal surface which slopes slightly toward the center where it connects with the riser or water leg. This new type of tank bottom has been given the name "toroidal" bottom. Figure 4 illustrates the general features of the design. The tank shell and a part of the suspended portions of the bottom are supported by a ring of heavy rolled section columns which connect to the tank shell as in the customary design. The flat portion of the bottom is supported by a number of heavy rolled section radial girders which in turn are supported by interior columns, two of which support each girder in such a manner that great economy of the metal in the girder is secured. Between the radial girders is a system of grillage beams which carry directly the plates forming the bottom of the tank.

The inside surface of the bottom is smooth so that the entire tank contents will drain into the riser pipe and the tank may be easily cleaned and maintained. The bottom plates may be of either riveted or welded construction. The design is particularly suited to welded construction.

The welded bottom construction is somewhat similar to the battle-deck steel floor construction which has received publicity in recent

months. Since the plates are practically flat, the load on the plates is carried by them in flexure or cross bending and since there are a great number of supports the condition of loading is similar to that of a beam with uniform loading over continuous supports. Since, the plates are supported, however, on all four edges and since any slight flexure of the plates greatly increases their strength because of the catenary shape assumed, the bottom has a very great surplus

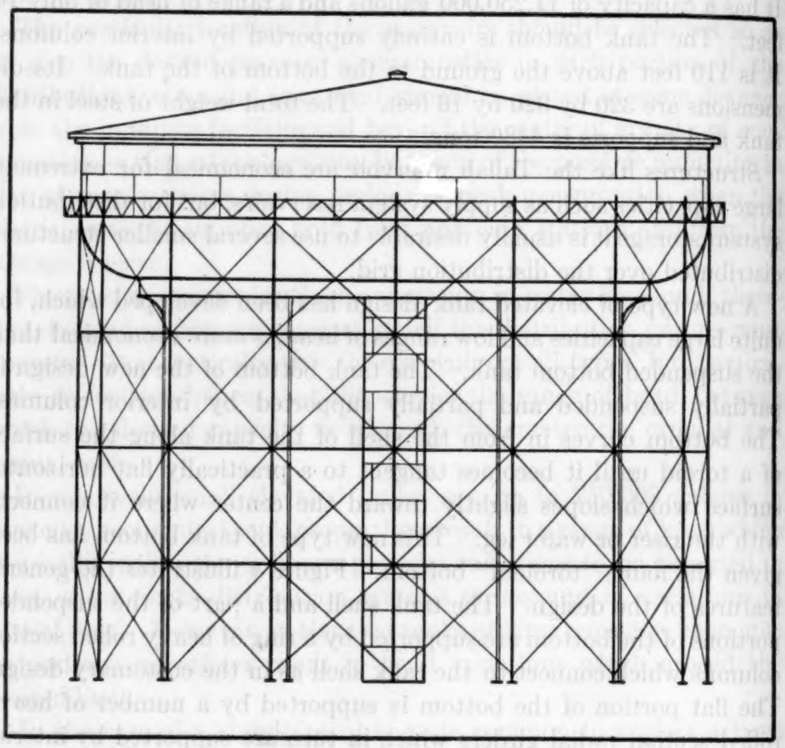

FIG. 4. TYPICAL DESIGN—TOROIDAL BOTTOM ELEVATED TANK

strength. In the case of the welded design, the strength is still further increased by the continuous joint between the plates and beams.

Formulas for the calculation of the stresses in the plates have been developed, using as a basis the theorem of three moments, and in order to verify these formulas, a full size section of the welded bottom construction was made and tested under the supervision of the Pittsburgh Testing Laboratory. The test tank was 10 feet in

diameter with a standard flanged and dished head at one end and a section of the toroidal bottom welded floor construction at the other end. The floor was inverted for convenience in taking extensometer readings at the various critical points and the load was applied to the floor by hydrostatic pressure on the interior of the tank.

Since tanks of this type are usually designed for ranges of head from 20 to 25 feet, the water pressure on the bottom would ordinarily be from 8.7 to 11 pounds per square inch. The test tank was designed for 10 pounds pressure, and at this pressure the deflection in the center of the plates was 0.28 inch, and the extensometer readings over various portions of the plates indicated that the maximum fibre stress agreed almost exactly with the formulas developed.

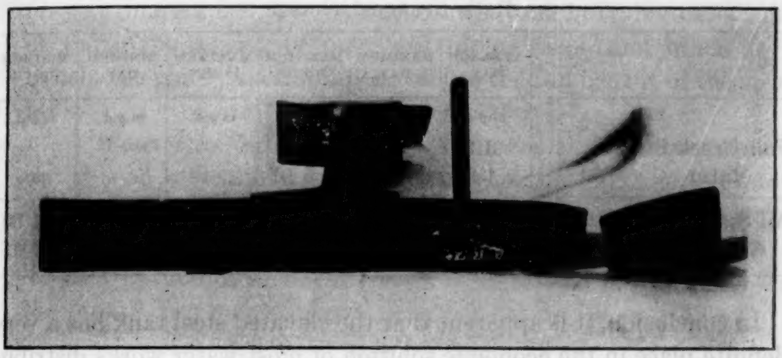

FIG. 5

In attempting to determine the maximum strength of this type of construction, the pressure was increased in increments of 10 pounds until at a pressure of 108 pounds per square inch or over ten times the designed working pressure of the tank bottom, failure occurred by shearing ten $\frac{3}{4}$-inch diameter rivets connecting one of the large girders to the shell of the tank. At this pressure there was no failure whatever in the welded bottom construction and it is interesting to note that not only the shell of the tank itself, but the dished heads had deformed to such an extent that the circumference at the connection of the dished head with the tank shell was reduced $3\frac{3}{8}$ inches. A complete technical report of this test will be available in bulletin form.

In order to secure further information as to the strength of the welded construction, sections of the bottom plates and supporting

beams were cut and tested in several ways. Figure 5 shows a section of the plate and beam which was pulled to failure, the rupture occurring near the grippers of the tesing machine at an ultimate strength of 54,200 pounds per square inch. A section of the welded plate construction was bent outwardly at right angles, causing severe punishment to the welded joint, which however showed no signs of failure. Another section of the plate was bent inwardly without failure of the weld and two sections of plate, but welded together, were bent around a ½-inch diameter pin without failure, showing the ductility of the weld.

TABLE 6

Variation in pumpage demand, Indianapolis Water Company, during year 1930

Ratio to annual average

	AVERAGE DAY	MAXIMUM DAY	MAXIMUM HOUR	MAXIMUM 15 MIN.	MINIMUM DAY	MINIMUM HOUR
	m.g.d.	*m.g.d.*	*m.g.d.*	*m.g.d.*	*m.g.d.*	*m.g.d.*
Fall Creek Station......	3.31	7.18	16.6			
Ratio	1.00	2.17	5.01			
All Stations............	34.54	55.67	112.2	123.4	24.56	14.00
Ratio...............	1.00	1.61	3.25	3.57	0.71	0.41

In conclusion, it is apparent that the elevated steel tank has a very definite place in the economic solution of most water works distribution problems and that it is possible to effect important savings in the original cost and annual operating expense of most water works systems by incorporating a proper amount of advantageously located storage of the most suitable type.

DISCUSSION

W. C. Mabee:[5] In addition to what has been presented by Mr. Jackson, the speaker wishes to add the following comments touching certain refinements in the development of devices for rendering elevated tanks more useful.

TANK LEVEL INDICATION IN PUMPING STATION

To use elevated storage efficiently, it is essential that the pumping station operator have accurate information regarding the stage of water in the tank or tanks at all times.

[5] Chief Engineer, Indianapolis Water Company, Indianapolis, Ind.

By means of remote metering devices this information can be transmitted electrically through the medium of the local telephone exchange, even though the stations be separated by miles. In freezing climates it may be necessary to resort to mercury actuated transmitters, unless the floats can be protected otherwise.

By means of charts, a permanent record can be made for inspection and review at any time.

Signals indicating high and low tank levels may be actuated by these devices.

TANK CONTROL DEVICES IN INDIANAPOLIS

The Indianapolis Water Company has under construction at the present time a 1,500,000 elevated storage tank in Irvington, a suburb of Indianapolis, and proposes to employ these and other devices to help the plant superintendent realize the full benefit of the storage tank.

(a) *Water level indicator:* The instrument that will transmit the water level indications from the tank to the Fall Creek Pumping Station will operate over leased wires. These indications are accomplished by means of a float riding on mercury, operating in one leg of a U tube of sufficient length to balance the head of water in the tank. The manufacturer describes his device as follows:

"This float controls a transmitting device, the output of which is direct current varying in proportion to the position of the float-controlled transmitter

"The receiving equipment then simply consists of milliammeters of the indicating and recording type. The use of this system prevents the record being interfered with by changes in resistance of the telephone line, or by changes in the supply voltage."

It was specified that "The allowable electric load for the conductors will be 135 volts positive or negative d.c. between conductors and ground, or 270 volts across the pair direct current. The current limitations will be .1 ampere on any one loaded conductor direct current."

(b) *Altitude valve.* The tank in operation will "float on the line," except at certain seasons, and will be provided with an altitude valve to prevent overflow and to maintain storage control. The operation of the valve is entirely automatic, actuated by a hydraulic cylinder. A time clock will be installed, which when set will hold the stored water during the off-peak hours, releasing the storage at a predeter-

mined time when the demand is heavy. This feature will only be brought into play during the heavy pumping season of mid-summer; otherwise it is inoperative. The valve is so designed that it will close from the open position at any given elevation on the tank and will automatically open with a drop in pressure of about two pounds, or more as desired, unless controlled by time clock.

The hydraulic cylinder referred to is actuated by the opening and closing of a solenoid operated control valve energized with 110-volt 60 cycle A.C.

Contact is made by means of a "Mercoid" pressure switch which opens or closes the electric circuit with a change in water pressure. Interruption of power service closes the altitude valve; when the power comes on the valve resumes its former position. Furthermore an interruption in power is reflected at the receiving end of the transmitter, thereby calling the operator's attention to the fact.

(c) *Gate house.* The valve pit with its superstructure containing these instruments is located at the base of the riser pipe. It is built of insulating material; electric heating elements are also installed to prevent freezing of the small water piping.

FOUNDATIONS FOR TANKS

The question of foundations may prove of interest. In considering foundations for tanks of any magnitude it becomes an important matter to have definite knowledge concerning the bearing value of the particular soil upon which the tank is to be built, in order to guard against failure. It is fully as important to analyze the foundation design as the structure it supports.

Too frequently the designer makes assumptions as to the safe bearing value of the soil from an inspection only of subsurface specimens and decides that the soil will sustain a certain load without undue or unequal settlement. He is guided by regulated safe bearing values found in building codes under certain classifications of soil.

If the designer's classification proves to be in error, the results may be serious. When there is a doubt, the designer should cause tests to be made to determine the limit of compactness and the bearing capacity limit of the soil, or ultimate load point where displacement begins.

Empirical rules of procedure or interpretation of test results are scarce.

The Building Commissioners of New York have such a rule which is frequently quoted in text books. It provides that the test shall be made over an area of not less than four square feet, that the accepted safe load shall not exceed two-thirds of the test load and that the test load shall show no settlement for at least four days.

The Progress Reports of the Special Committee of the American Society of Civil Engineers on Bearing Value of Soils for Foundations presents the ground work for the development of science along these lines of research.

"The Science of Foundations—Its Present and Future" is the subject of paper No. 1704 by Charles Terzaghi, Member American Society of Civil Engineers, published in the Transactions of the American Society of Civil Engineers on page 270 of Volume 93, 1929. This paper with discussion forms a valuable treatise of the subject. "The paper reviews the present stage of the science of foundations, its principal short comings, and the possibilities for its improvement."

The Department of Engineering Research, University of Michigan, Ann Arbor, has published Engineering Bulletin No. 13, October, 1929, entitled "A Practical Method for the Selection of Foundations Based on Fundamental Research in Soil Mechanics" by Professor W. S. Housel.

This publication is also a valuable contribution to the subject. The author develops physical-characteristic coefficients for large or small areas and gives charts for graphical solution of foundation problems. Quoting from his summary:

"1. The bearing capacity of soil has been found to be dependent upon two separate and measurable factors, defined as perimeter shear and strength of the pressure bulb.

2. The straight-line relation of bearing capacity to the relative size of the bearing area has been formulated for equal amounts of settlement."

Other conclusions of value are outlined which space does not permit repeating.

References to bibliography on this subject may be found in these papers.

ELEVATED STORAGE

Since it is becoming more generally recognized that elevated storage affords a valuable adjunct to the arterial system, water plants in increasing number are availing themselves of this advantage. The

trend of this development is toward tanks or reservoirs of larger capacity, or a multiplicity of relatively smaller units.

Whether this storage is in underground reservoirs on elevated ground, as in Louisville, for instance, or in elevated storage tanks, as in Indianapolis, depends in large measure on the availability of sites in the proper localities and with proper elevation to act as gravity supplies.

SOME ADVANTAGES OF ELEVATED STORAGE

(1) In a rapidly growing community, pipe lines are extended from time to time into new sections. Many times these growths are on higher ground than the general level of the city. The demand for water in increasing quantities gradually adds a burden on the pipe system, which, at times, exceeds the capacity of the system to supply. The situation may become acute when a drought similar to that experienced in 1930, is encountered. Under these circumstances the pumping machinery and the pipe system are both overtaxed. The situation can be greatly relieved by introducing elevated storage, the location depending on local conditions. An engineering study of the problem will develop the proper procedure for installing the storage that will serve the district to the best advantage. It will also indicate where additional incidental feeder mains are necessary.

(2) It may well be found that elevated storage, properly connected to the pipe system will prove to be more economical in first cost than the extension of adequate reinforcing mains from the pumping station into the district. The latter usually involves additional supply mains from the source, and also additional plant facilities.

After the installation of elevated storage, it will usually be found that part of the pumping equipment will be released for reserve pumping capacity, and the pipe lines will be restored to their former adequacy, thereby increasing the dependability of station operation with a greater factor of safety on reserve pump capacity.

This favorable position is brought about by the utilization of the off-peak pumping hours for refilling the storage reservoirs or tanks and avoiding the excessively high pumpage rates during the on-peak hours.

Filling during the night and withdrawing during the day tends to equalize the pumpage rate throughout the 24 hours. It also provides more nearly constant pressure and consequently improves the water service during the hours of greatest need.

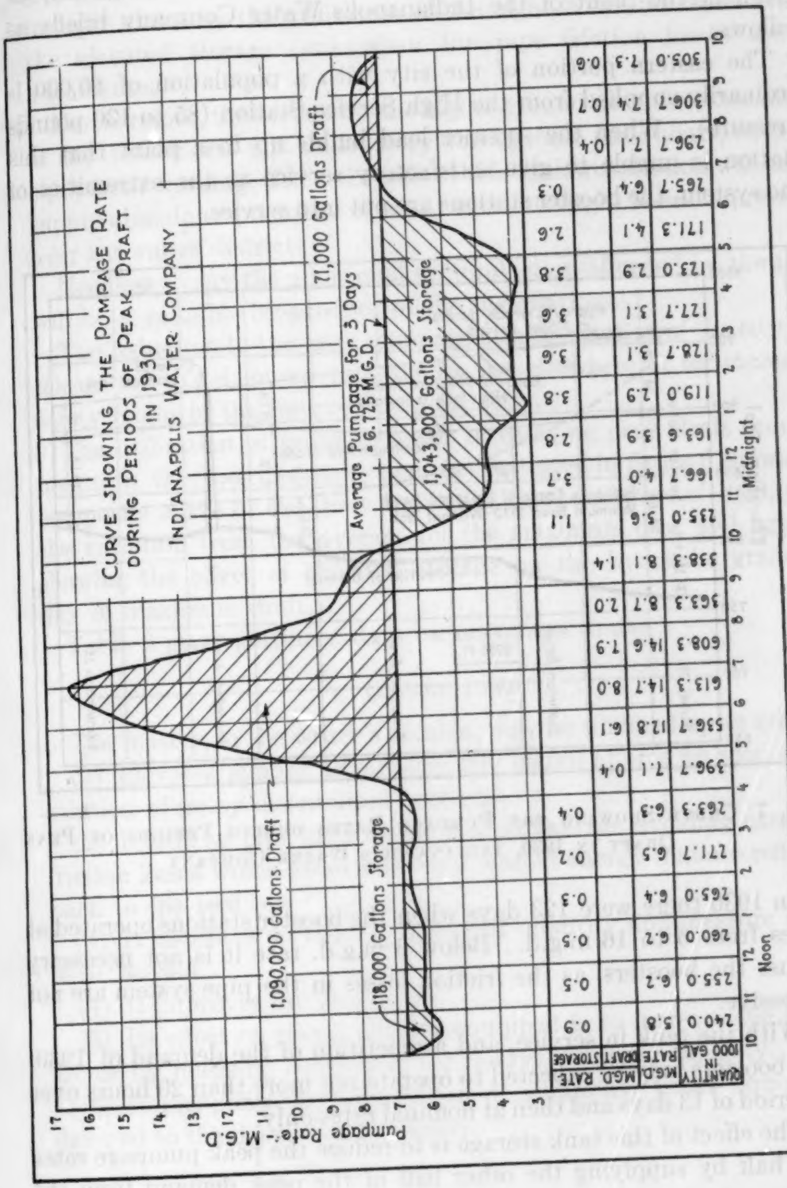

FIG. 6. EFFECT OF ELEVATED STORAGE ON HYDRAULIC GRADE—INDIANAPOLIS WATER COMPANY, 1931

(3) An example of advantageous use of elevated storage may be given in the plant of the Indianapolis Water Company briefly as follows:

The eastern portion of the city with a population of 50,000 is ordinarily supplied from the High Service Station (85 to 130 pounds pressure). When the summer load builds up to a point that this station is unable to give satisfactory service at the extremities of the system, the booster stations are put into service.

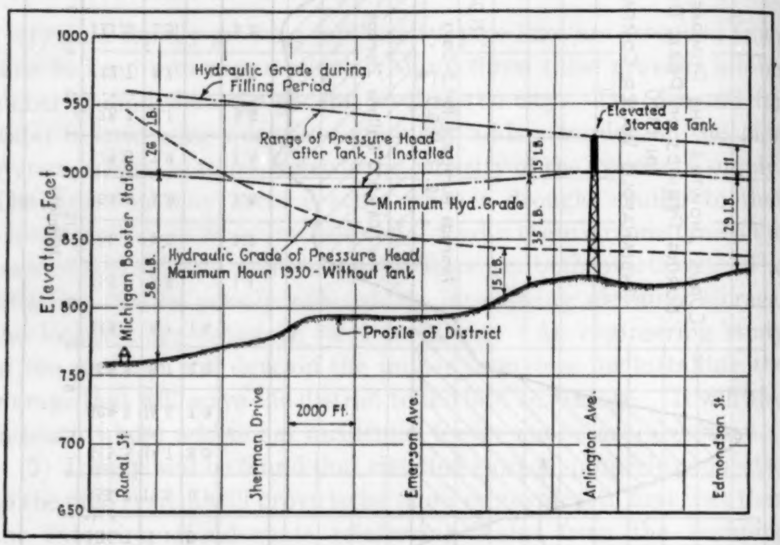

FIG. 7. CURVE SHOWING THE PUMPAGE RATES DURING PERIODS OF PEAK DRAFT IN 1930, INDIANAPOLIS WATER COMPANY

In 1930 there were 123 days when the booster stations operated at rates from 6 to 16 m.g.d. Below 6 m.g.d. rate it is not necessary to use the boosters, as the friction losses in the pipe system are not excessive.

With the tank in service, and a repetition of the demand of 1930, the boosters may be expected to operate not more than 20 hours over a period of 13 days and then at nominal rates only.

The effect of this tank storage is to reduce the peak pumpage rates one half by supplying the other half of the peak demand from the tank.

In this case the saving in electric energy charges to overcome exces-

sive friction head losses in feeder pipes is a substantial sum. This is brought about by the utilization of the night hours for replenishing the elevated storage tank when the pipe friction losses are at a minimum.

Furthermore, the service on the higher ground near the extremities of the district was not satisfactory during these peak hours, with all equipment working. The net result of this tank installation will be to supply abundant quantities of water with but slight losses in pressure over the entire district.

Needless to say the additional fire protection afforded by the tank will be a valuable by-product of the installation.

The reduction in the peak pumpage into this section of the city will release 9.0 m.g.d. pump capacity for use elsewhere or for increased safety factor of the reserve pump capacity.

The utilization of tanks to assist in carrying peak draft requirements in the distribution system is illustrated in figure 6 showing a composite curve of the three maximum days' pumpage of 1930, with the variation from the average for the maximum day, and figure 7 showing the effect of elevated storage on the hydraulic grade on day of maximum draft.

Table 6 gives pertinent data on maximum drafts.

CONCLUSIONS

The matter, in the writer's opinion, may be summed up as follows:

(1) Elevated storage advantageously placed affords an economical solution of many distribution problems.

(2) It utilizes pipe lines to the best advantage avoiding excessive friction losses which losses represent wasted energy that are reflected back to the coal pile.

(3) It improves service by supplying quantity and pressure where most needed.

(4) It improves fire protection.

(5) Its effect on plants already equipped is to increase the safety factor by releasing equipment for reserve pumping capacity.

(6) It postpones the installation of additional plant equipment devoted to the distribution of water.

ALLOCATION OF WATER

By Harold Conkling[1]

In most parts of the arid states, agriculture can be successful only if the streams can be diverted to water the fertile soil. By the time the state of Colorado was ready to be admitted to the Union there has been opportunity to consider the effect of certain tenets of the common law in connection with the conditions of the arid west, which are so vastly different from the lands of England where it was developed. It was evident to forward looking men that water, not land, would limit the area which could be farmed and that, contrary to conditions in eastern United States and in England, the greatest benefit of water could be obtained by spreading the streams to the largest area possible, no matter how far distant from the parent streams it might be carried. The common law doctrine of riparian rights militated against this. The framers of the constitution of Colorado, therefore, broke away from precedent and wrote into the constitution the following:

> "The water of every natural stream not heretofore appropriated is hereby declared to be the property of the public and the same is dedicated to the use of the people of the state, subject to appropriation as hereinafter provided.
>
> "The right to divert the unappropriated waters of any natural stream for beneficial uses shall never be denied. Priority of appropriation shall give the better right as between those using the water for the same purpose.
>
> "All persons and corporations shall have the right of way across public, private and corporate lands for the construction of ditches, canals and flumes ****upon the payment of just compensation."

In other language, the constitution recognizes use of water for all purposes as a public necessity, declares it the property of the state and establishes beneficial use as the measure of the right which may be claimed. Arizona wrote a similar provision into her constitution when admitted to statehood. Idaho, New Mexico and Wyoming in their constitutions, declared the waters of the state to be the property of the state and subject to appropriation, but did not de-

[1] Deputy State Engineer, Sacramento, Calif.

clare the riparian right abrogated and for this reason legislation and court decisions were found necessary to fully do away with the riparian doctrine. The courts of Montana, Nevada, Oregon and Utah and Washington have declared the common law doctrine unsuitable, although in Oregon and Washington it is not abrogated entirely, and by such decisions these states are placed on practically the same basis as those with definite constitutional provisions. In Kansas, Nebraska, North Dakota, Oklahoma, South Dakota and Texas, which all lie only partly in the arid region the riparian doctrine still obtains but is so modified from its original form that it can be said that in the arid portions of these states it does not interfere seriously with allocation of water through the appropriative doctrine and administration of the streams.

Of all the western states, California alone, through court decisions, persists in the riparian doctrine almost as it exists in the eastern states, although the state legislature has repeatedly declared ownership of the water to be in the state. The fate of a recent constitutional amendment modifying the riparian claim to encompass only water which could be beneficially used in accordance with practice under appropriative rights remains undecided as yet. Ironically, it was in California that the principles of the appropriative doctrine were first developed during the heyday of placer mining following the days of "49." Large diversion from streams was necessary for that industry. In all the remaining states of the Union the common law doctrine of water rights is the rule. When these states were settled there was no thought otherwise and only in recent years, with the development of large urban populations on the eastern seaboard, have some of the states in the humid region recognized the desirability of more unhampered distribution of water. In other words, these states have only recently faced a condition which has existed since the beginning of development in the western states.

It is the purpose of this paper to describe the procedure developed for allocation and administration of streams under the appropriative doctrine. It is hoped that discussion will develop the procedure used in those eastern states wherein administrative state bodies have been set up to deal with water. Such description as this paper attempts would be incomplete without a clear conception of the basic law on which the structure has been built and the fundamental difference between the basic law of appropriation and beneficial use, and the common law of riparian rights which prevails in most of the

states of the Union. To be sure, there is nothing to prevent states in which the riparian doctrine prevails from superimposing a procedural code modelled after the codes of the appropriative doctrine states. California, which is one such state, has set up a code which occupies 40 closely printed pages dealing with procedure in obtaining water rights by appropriation and administrative procedure. It is adapted from the codes of Wyoming, Oregon and Nevada but administration of the code is sadly hampered. So far, its main accomplishment has been an orderly record of proposed appropriations and their progress or death as the case may be. It has perhaps prevented litigation also by providing an office where the facts were readily accessible. As to providing a straight path from the inception of an appropriation to the administration of the stream to insure the appropriator in getting his water without conflict with other rights the code has not been successful, largely because the basic riparian doctrine interferes with the procedure. While streams supplying a very large acreage in the state are under administration by the state, yet this has come in a more or less roundabout way and not in the general way provided in framing the code. It has come through minor provisions in the code rather than through the application of the basic principles and procedure established in the appropriative doctrine states. Inasmuch as successful administration of a stream is based on definition of the rights and police power, and not on legal doctrine, such administration can, as has been demonstrated in California, be as successful in streams under riparian doctrine as under appropriative doctrine, provided the courts are willing to adjudicate the rights in a body and provided that either through the court or the legislature an administrator with proper power is appointed. Where use of water is non consumptive, however, as it is in the humid states except for municipal diversions, such administration becomes relatively unimportant.

Because of the necessity of a full conception of the difference in the basic law, a large part of this paper is occupied with an exposition, in as brief a form as possible, of the merits and limitations of both the appropriative and reparian doctrines, together with some discussion of a trend toward a new doctrine, or perhaps more correctly, a new application of the older doctrines.

It is not to be supposed that the appropriative doctrine as now set up is the final word. Just as the riparian doctrine gave way to the appropriative doctrine so will the appropriative in its present form give way to something else if development finds that such is needed.

PRINCIPLES OF LAW

In general, the common law is the legal recognition of economic and natural conditions and customs resulting therefrom. Light, air and flowing water are three phenomena of nature to which each person who has access should be allowed free use and enjoyment so long as he does not interfere with similar use and enjoyment by others. All people have access to air and light, but only those owning the land bordering a stream, that is, the riparian owners, have free access to flowing water. Hence all others are precluded from its use under the common law. Furthermore, under climatic conditions in England from which our common law derives, it was not necessary to dissipate and consume the stream for irrigation, and the most important use was for power in turning mill wheels. For this reason the greatest use could be obtained if the volume of the stream was undiminished. As it stands today the doctrine has been modified somewhat in the United States and any use whether consumptive of water or not is appurtenant to the riparian right so long as the other riparian owners are not unduly injured. The right to use of the water attaches to the land. It does not cease with lack of use and can be asserted at any time. Each man's right is governed by the rule of reasonableness, not as against the public, but as against other riparian owners. The right is correlative and not exclusive.

Under the appropriative doctrine each right is set in a scale or framework, as it were. It endures so long as the water can be used beneficially and when it cannot the water may not be diverted but reverts to the stream whence it may be taken by the next claimant. Thus for irrigation use in the colder states it terminates each season when winter begins, unless it can be stored during the winter, and starts when spring comes and water is necessary for the growing crop. It terminates permanently by a series of years of non use. A fundamental of the doctrine is "First in time, first in right." If a series of appropriative rights in a stream be platted on a graph they will appear as a series of horizontal lines, one above the other. Water is available to each right when the stream flow is large enough to fill all rights lower on the scale. If the daily flow of the stream be also platted on the graph it will be found that for the later rights which will be platted highest on the graph, water is available during a fewer number of days than is the case for the prior rights. When natural flow is not sufficient to fill a right the supply must come from storage if it comes at all.

The definiteness of the appropriative right lends itself quite readily to codification of procedure in acquiring the right, and most important, administration of the stream to see that each right gets the water to which it is entitled. In addition to the ease of definition the importance of water in the economy of the arid region makes it naturally fall under detailed supervision of the sovereign power to a much greater extent than would be the case otherwise. The variability of stream flow demands stream supervision also, if the theory of the appropriative right is made effective. Not all states in which the appropriative doctrine prevails have adopted codes, but they have been adopted in those states where large use of the streams has been made and vary to a considerably degree in their elaboration. In general these codes have a procedure for adjudication of streams by the state official also, subject in most cases to confirmation by the court, but this is not the case in all. In any case the findings are subject to appeal to the court.

BASES OF STATE CODES

The object of a proceeding in law before a trial court is to get at the facts. The codes as adopted in most of the states provide a method of recording all facts in connection with a water right from its inception. If these codes had been in existence at the earliest dates and if funds ample for their administration had been provided there would be no need for court actions to determine facts and no need for the adjudication procedure embodied in many of the codes.

It is proposed to describe the functioning of the more elaborate and complete codes as of the present. The various steps which have led up to the details of the codification are not important for the purpose of this paper. The procedure has gradually evolved and has three main phases:

1. The filing of applications, thus establishing the priority of the water right.

2. The adjudication of the right, thus establishing the amount of the right.

3. The administration of the stream, thus assuring each water user that he is receiving the water to which he is entitled.

APPLICATIONS

When the code so requires no diversion from the stream may be made except by permit from the state. This is required in most of

the appropriative doctrine states having codes and also in California which is not an appropriative doctrine state. It could be required in any state having the riparian doctrine, if the legislature desires and there are no constitutional prohibitions. The would-be user makes application to the administrative office for a permit on appropriate forms furnished by the states. These forms are gotten up in considerable detail and when the application is finally completed give a very accurate description of the project and method of use. Maps are also required. Separate applications are required for municipal, irrigation and power uses and for all other minor uses, except incidental domestic use. This gives the applicant a prior right (that is, prior to all subsequent applicants) as of the date application is received in the state office. When first filed the applicant is required only to state the proposed point of diversion, the amount desired, character of use and place of use. He is then given a period of time in which to make surveys and file maps showing his project. Steps are then taken to determine whether there is unappropriated water available. The proposed appropriation is advertised and in case protests are received, a hearing is held. This procedure, however, varies considerably in the different states. If there is no unappropriated water, that is, if discharge sufficient in volume after all prior rights are satisfied does not occur with sufficient frequency to make the project feasible the application is rejected. It may be also rejected because opposed to public interest, although in some states this may not be done and such a rejection is very rare inasmuch as it smacks too much of exercise of judicial power. If a permit is granted, it is for an amount which is found can be used beneficially and the applicant is given a period of time to construct his project and an additional period to put the water to use. A power development might put all its water to beneficial use almost immediately after construction is completed, but an irrigation project such as the large ones recently constructed might require fifty years or more and this is also true of a city. The project is kept under observation by yearly reports and inspections, if necessary. After use is completed, a license is issued in some states to so much of the water right as has been used beneficially and this license fixes and determines the water right. It certifies that the licensee has the use of a certain amount of water to be diverted at a certain point during a certain season whenever stream discharge is sufficient to fill his right. He may store it for later use or use it directly. It states

that he has a priority as of the date of his application. In effect, it adjudicates his right in the priority scale and as to amount and use, relative to all other rights on the stream in a body.

Thus there are three definite steps, the application, the permit, and the license which corresponds to a deed to land but which is revocable through non use. As stated a license is not issued in some states and there are certain practical objections to its use.

ADJUDICATIONS

If such detailed procedure as the above had always existed in all the states and if, in addition, abandonment of all or part of a right had been recorded, adjudications would not be necessary. The codes are in a state of development, however, and as yet have been perfected to the degree described in only a few of the states. Even in those with the most detailed codes the facts as to old rights are not well known without additional examination. A stream can be administered only after the rights have been adjudicated relative to priority and amount and a rule thereby laid down for the administrator to follow. The code sets up a procedure whereby the state can initiate an adjudication of all the rights on a stream and provides for hearing both by the administrative office and subsequently, if necessary, by the courts, wherein the facts gathered can be made known and interested parties can present their case. After decree by the court the stream can be administered. Some codes provide for administration if an agreement as to the rights can be reached by the parties themselves without the intervention of the state and without reference to the court.

In addition to the general adjudication of the whole stream, adjudications are often the result of court action initiated by a water user asking protection from invasion by another user generally upstream. In too many cases these actions are between only a few users and other users are not involved, so that most cases of this kind form only a partial rule at best and are unsatisfactory for stream administration. An adjudication should determine the rights of each user on the particular section of the stream involved. The court can refer a case to the state for determination of facts and in such cases the state may advise bringing in all users on the stream.

STREAM ADMINISTRATION

Even if each right has been determined as to priority and amount yet no guarantee exists that the lower user will receive his water.

The upstream user will naturally take all the water at his diversion works up to the limit of his diversion capacity. He has no reason to be interested in the rights of others and even if he were and conscientiously sought to refrain from diverting water not belonging to him it is patently impossible, with the stream discharge constantly changing, for him to know at any particular time whether the prior right lower on the stream is receiving water or not. He may be separated from the diversion works of the lower right by hundreds of miles of territory.

This situation necessitates an official for each stream who knows from day to day and almost from hour to hour the stream discharge and the diversions. It also necessitates constant patrol of the stream.

The official is called by different titles in different states, and functions under the central authority. His organization may be elaborate or simple depending on the stream. He is clothed with police power. Diversion works are under his jurisdiction and changes in amounts diverted may be made only by him or his delegated representative. When the stream falls and the later rights terminate he must close their diversions and the water thus allowed to remain in the stream may travel hundreds of miles before it is diverted by the next prior right. When it rises he must open the diversions if water is desired. It is his function to see that each water right gets the amount of water due it.

He must allow for return flow and tributary flow. He must know the rate of travel of flood peaks and reservoir releases and ordinary stream flow. He must know the schedule of priorities. He must know evaporation from the stream bed reservoirs in order to charge it to the right owning the reservoir. His office may at times resemble a train dispatcher's with telegraphic advices from all over the system arriving at frequent intervals and with instructions going forth.

In Colorado, for instance, under the state engineer are 7 division engineers each controlling a stream system. Under these are 60 water commissioners each controlling a section of a stream system. For the more important areas there are deputy water commissioners, also, the total of these being 100. There are also 6 hydrographers recording stream flows daily at different points.

The foregoing is the briefest review possible of the three principal functions of the offices in the western states which have been set up to handle stream systems and water rights. The functioning of

those having the most elaborate codes has been described. Only a few have been thus fully codified and the elaboration in many of the other states is much less.

COMPARISON OF DOCTRINES

And now the merits and faults of the two doctrines may be more definitely indicated. The riparian doctrine interposes an obstacle to development of a stream. Its basic idea no doubt was that a stream should flow in its natural regimen and the idea of use was probably superimposed at a subsequent time. The riparian right does not extend to conserving the higher flow by storage and the riparian owner can resist any one who seeks to do this by appropriation. In most cases the really beneficial flows are the low flows and these have been put to use long since, where opportunity exists. Loss to the riparian owner by storage of the high flows is generally a small matter, but through difficulty in getting the true value before a jury, awards in condemnation suits are often excessive. An interstate stream offers especial complications in condemnation.

The riparian doctrine while of limited usefulness and in fact detrimental when conditions have passed the primitive stage, yet has for the state of development to which it is suited, a certain equity, at least in theory. In times of drought all would suffer equally. However, the remedy for unreasonable use by one against the other is in the courts and is therefore too slow and uncertain for efficient application to so fugitive and rapidly changing a thing as stream flow. In California, however, this has been overcome by a general adjudication of many streams by the courts which have appointed the state water administrative body the referee. These adjudications cover both appropriative and riparian rights. The reference is in some cases limited to determining the facts, in others to preparation of a schedule after determination of facts and in still others broader powers are given by the courts. After adjudication a water master is appointed by the state to administer the decree.

On the other hand, the appropriative doctrine in spite of its merits previously noted puts an extreme burden upon the later users for whom water is available so infrequently that long time holdover storage must be built to make a water right useful. It tends for this reason to inhibit development also, but at a later stage in development than is the case with the riparian doctrine.

COMPACTS

Actually, however, practice does not always accord with law. Actuality goes ahead of, or lags behind the code. Conditions change faster than law. Diversions by appropriation are made in spite of the riparian owner and often without protest from him. These may ripen to prescriptive rights against him. Late priorities under the appropriative doctrine, if upstream, encroach on older ones and if storage is required to complete both the senior and junior rights, some of the burden of securing it is sometimes placed on the older ones. A stream together with all tributaries is seldom administered through its entire length in accord with priority. The more favorable areas were irrigated first and these have the best and cheapest water right under the appropriative doctrine, yet these areas are best able to pay the higher costs for water. Pressure of one kind or another has brought about some yielding by the early rights, but the process has been a long and costly one. Sometimes through sheer helplessness, particularly in the larger stream systems, and especially in those which flow through several states, the older rights have stood by while later rights have taken the water. This condition has doubtless led to a greater development than would be the case had the later rights always been held down to the water which they would have acquired under strict application of the rule. In addition, return flow from irrigated areas very often gives a complete supply to the lower rights no matter whether they are junior or senior.

Partly in recognition of the difficult conditions created by the appropriative doctrine, after the earlier stages of development have been passed, some demand for modification of its universal application has arisen. The influence of certain physical conditions has reinforced this demand. What is known as the compact has been proposed and in some cases adopted. To date compacts have been between states. In the west the outstanding compact is that on the Colorado River. This failed of approval by Arizona, one of the seven states affected, but by consent of Congress was made effective by the approval of the six remaining states. This compact had its rise in the fear of the upper states of the Colorado Basin that the states of the lower basin, more favored climatically and in market for power which can be developed on the river, would get control of the surplus of the river before economic conditions would enable use in the upper states to develop. This result would be strictly in accord with the principles of the appropriative doctrine which is the

basic law of all the Colorado Basin states, except California. The compact prevents full functioning of the doctrine and dedicates water to a certain area regardless of beneficial use and in that respect is not unlike the riparian doctrine. It allocates a portion of the river to the four upper states in a body, but does not divide it among them. It does however allocate specific quantities to each of the three lower states. It is expected that within any one of the states the water allocated to it will be distributed according to the principles of the appropriative doctrine. Other compacts have been completed between states in the west, among which are those on the South Platte and Rio Grande and the La Plata Rivers. In the east a compact on the Delaware river between New York, New Jersey and Pennsylvania has been negotiated, but not approved by the legislatures of the several states. This procedure seems applicable on any stream whether the states through which it flows are riparian or appropriative, although doubtless the difference in basic law would modify the features of the compact.

It is not known how successful these compacts will be in actual ultimate operation, but at least they tend toward orderly development until their imperfections became manifest at some future time. The question suggests itself as to whether the same device would not be useful between different sections of a stream within the same state. As a matter of fact what amounts to the same thing exists to a degree today through encroachments as before mentioned and through recognition to an extent of the limitations of the appropriative doctrine, especially when the stream is a long one and physical conditions are favorable and if the law is not strictly enforced. The law of priority is very difficult to enforce under some circumstances, notably when an upper right must be cut off to fill a right far distant downstream.

CALIFORNIA PARTIALLY APPLIES PRINCIPLE OF COMPACT

In California a partial application of this principle of the compact appears in withdrawals by legislative action of the unused water of the streams of the Sierra Nevada mountains and by certain more definite withdrawals proposed, but not yet made effective. These are in general for the more backward areas of the state or to insure against limited developments by private interests which will militate against an ultimate economic plan which is now proposed after ten years investigation.

It may be said that the riparian doctrine is becoming unsuited to

certain eastern sections where rainfall is abundant, but where diversions must be made because of necessities of numerous urban centers. However, it could not create the same difficulties in the eastern states as it could in the arid states because condemnation costs are a more serious matter for the farmer than for an urban community. The delay and uncertainty might, however, be a grievous detriment to both.

As yet the riparian doctrine has probably not stopped any considerable development which has become necessary, but it has placed an impediment in the way in certain cases. In California, which contains the largest irrigated area of any state in the Union, there are 4,730,000 acres now irrigated of which at least 50 percent is by appropriation, and there are 2,000,000 acres additional under ditch and having a water right (not always sufficient), but not irrigated because of lack of demand for farm products. This two million acres has, in the main, appropriative rights. In Colorado which is the next state in area of irrigated land there are 3,420,000 acres irrigated. The basic law of California is the riparian doctrine and Colorado is the foremost exponent of the appropriative doctrine. Evidently human needs govern the rate of development rather than law.

STATE REGULATION

Where diversions of a stream in considerable amount become necessary a state body has been set up in all states whether the basic water law is riparian or appropriative. On the one hand, this body derives its authority from the necessity of the sovereign state to exercise control over property of individuals under certain circumstances. Police power and zoning ordinances are cases in point. On the other hand, in appropriative doctrine or beneficial use states the water belongs to the state and it is under the necessity of administering its property wisely through the establishment of an appropriate office. Allocation of water in riparian right states could be benefited by authorizing the state office which administers the water to evaluate damage to the riparian owner caused by an appropriator and making it a prerequisite to going into court that the contestants, whether seeking damages or injunctions or evaluation for condemnation purposes, appear before such body and secure a decision. It would also be beneficial, if in certain cases damages could be recompensed by payment in kind rather than in money, in other words, if an equated and certain low flow were given in exchange for the

waters of the floods. The board's findings could be made prima facie evidence in case of appeal to the court.

The codes of the more highly developed appropriative doctrine states appear satisfactory. They are directed to one end and that is to give a rule and guide for actual administration of the stream. Administration is not always so perfect as the code nor always actually in accord with the basic principles, but in general as practised it is satisfactory to the water users. A compact whether interstate or intra-state allocating certain amounts of water to certain general areas of a stream might give a better ultimate solution than strict adherence to the appropriative doctrine.

DISCUSSION

Nathan B. Jacobs[2] and Arthur Skilling:[3] Apologies are due the legal profession for the apparent presumption of engineers in undertaking to treat the subject of "Allocation of Water" which is so much, at first blush, one of application of principles of law. The excuse for our trespass is the necessity for acquaintance at least with the fundamental precepts of water law in order that its applications, which are problems of engineering, may be in harmony.

This necessity must be patent. Take for example, an obvious case. When John R. Freeman wrote his report on the Water Supply of New York City in 1900, he found the cheapest and most available source for additional supply was the Ten Mile River combined with the Upper Housatonic. Ten Mile River is in New York State at the proposed point of taking, but just before it reaches its limit and joins the Housatonic it crosses over into Connecticut. Mr. Freeman recognized the legal obstacles in the way of diversion of this stream by New York and he included a statement of them in his report, even though he thought they could be overcome and New York's right to the Ten Mile project established. As a result of further legal investigation subsequent to the report, it was decided that the law was too strongly on the side of Connecticut to make the successful development of the source attractive and the project was dropped. Here was an example of an acquaintance with law used to deter a client from an unwise plunge into a project beset with legal entanglements.

[2] Vice-President and Assistant to Chief Engineer, Morris Knowles Incorporated, Pittsburgh, Pa.

[3] Assistant Engineer, Morris Knowles Incorporated, Pittsburgh, Pa.

The paper under discussion is both an excellent primer for the novitiate in water law and a comprehensive statement of the status of the appropriation doctrine in the west.

The arid region doctrine of appropriation says in essence that the right to water flowing in a stream may be acquired by appropriation for beneficial use. A man who has land to irrigate may take the water necessary for the irrigation from a stream, even though he does not own land bordering on that stream. He may take only such an amount of water as he can beneficially use. By so appropriating the water of that stream, and by using it for irrigation purposes for the benefit of his land, or applying it to other beneficial use, he becomes the owner of the water rights upon that stream.

In his comparison of the appropriation doctrine with the Eastern doctrine of riparian rights, the author finds that the latter "interposes an obstacle to development of a stream." In reaching this conclusion he is treating the doctrine without its very important corollary, the power of eminent domain.

The power of eminent domain is the one way in which the possessor of riparian rights can be deprived of them for the public good. It is the power which is [illegible] t[illegible] municipalities or to public water supply companies to take water for public use. Every act of the Legislature which gives that authority must of course contain a provision for the payment of damages; otherwise, such legislation would be unconstitutional and void. With this power, the doctrine of riparian rights has been no barrier to intense developments, as some of our water supply projects here in the East demonstrate.

The author goes on to say that "An interstate stream offers especial complications in condemnation." Many of these complications have been cleared away by two recent decisions of the United States Supreme Court, Connecticut v. Massachusetts, decided February 24, 1931, and New Jersey v. The State and City of New York, the Commonwealth of Pennsylvania intervenor, decided May 4, 1931. These two cases, which were almost exact parallels, were decided by the court, not on the basis of a strict interpretation of the riparian doctrine, but on what the court termed in the former case "equality or right" and in the latter case "equitable apportionment." The decisions approve the appropriation of the waters of an interstate stream by an upper proprietor within the limits of "equality of right" of "equitable apportionment," and at the same time they guarantee to the lower state immunity from the injury of any substantial interest by the appropriation above of undue amounts of water.

In both cases, the Complainants had pleaded for a strict interpretation of the law of riparian rights which would have entitled them to the flow of water in the river undiminished in quantity and uncontaminated as to quality. With such an interpretation of the doctrine affirmed, diversion could not have been permitted.

Even the power of eminent domain was not sufficiently broad to legalize the diversion. State authority stops at the state line and eminent domain is only state authority. New Jersey is a riparian owner on the Delaware River and New York sought to divert from some of the tributaries of that river. It made no difference that the tributaries were located in New York State. As riparian owner New Jersey owned the right to have the Delaware River flow undiminished in quantity. Such right has been held by the courts to be a property right, equally with the ownership of land, for example. New York then was in the position of desiring to take property from New Jersey and citizens in New Jersey, something that was outside the power of the New York legislature, even under eminent domain.

This was the question that these cases brought to the Supreme Court. There were other allegations in both complaints, but this was the essence of the bills in respect to the common law doctrine of riparian rights.

The decision granted the diversion, but at the same time it recognized rights of the lower states in both cases and the decrees provided for a substantial regulated release of water from the storage developments which are part of the diversion project. This release will amount to an increase in the flow of the receiving stream at times of low water. In the Massachusetts case, the amount of water to be released, which will actually increase the flow of the Connecticut River at times of low water, amounts to 146,000,000 cubic feet per year. The decree confines the release of this water to the period of low flow in the Connecticut River. The diversion originally proposed by Massachusetts was 205 million gallons per day, from an area of 284 square miles, all of which was in the State of Massachusetts.

The drainage area of the Connecticut River at the Massachusetts-Connecticut State Line is 9,722 square miles, and the average discharge is 11,000 million gallons per day, so that the diversion proposed amounted to about two percent of the annual average flow of the river at the Massachusetts-Connecticut state line. The original proposal of Massachusetts for diversion was modified by an order of the Army Engineers prior to the decision of the Supreme Court, with

the result that the total diversion was decreased by 14 million gallons per day.

New York sought to divert 600 million gallons per day from tributaries of the Delaware River located in New York State. The drainage area of the Delaware River above Tri-State Rock, the New York-New Jersey boundary, is 3,415 square miles and the average flow about 4,000 million gallons per day, so that the proposed diversion was 15 percent of the mean annual flow of the receiving stream. The court reduced this to 440 million gallons per day or to 10.9 percent of the flow of the Delaware River at Tri-State Rock.

In addition, the decree provides for regulated release of water from the storage reservoirs when the flow of the Delaware River at either Tri-State Rock or Trenton is less than 0.5 cubic feet per second. In other words, the court here, as in the Massachusetts-Connecticut case, has provided for a benefit to the main stream and consequently to the lower state. Low water flows will be augmented by release of water from the storage which the diversion project provides. In both cases the court saw to it that the lower state was not materially damaged by the diversion in respect to agriculture, pollution, fish life, navigation, power and the like, and then the court went a step further and provided a benefit to the lower state in augmented low water stream flow.

The decisions forward the cause of stream regulation under a new doctrine of equality of right, assuring to an upper state full benefit from waters within its borders and to a lower state immunity from material damage and a better river in extreme dry weather.

The effect of these two decisions on the future of interstate water compacts will doubtless be to limit their use or direct and guide their application. It would be to decry the decision of the courts to say otherwise, because certainly the decisions have added to our knowledge of water law. They have established the doctrine of equality of right. And where the equality of right is clearly established, there is no need in the future for litigation, and compacts can be more effectively drawn. Under these decisions, limited appropriations with an ample regulated release of water are approved.

W. L. STEVENSON:[4] Profoundly important questions in relation to the "Allocation of Streams" have been settled by the two recent

[4] Chief Engineer, State Department of Health, Harrisburg, Pa.

decisions of the Supreme Court of the United States in the Connecticut River and Delaware River cases. Very briefly a few of the outstanding quotations from the opinions of the Court as delivered respectively by Mr. Justice Butler on February 24, 1931 in Connecticut vs. Massachusetts, and by Mr. Justice Holmes on May 4, 1931 in New Jersey vs. New York, Pennsylvania Intervenor, are as follows:

"Drinking and other domestic purposes are the highest uses of water. An ample supply of wholesome water is essential."

"A river is more than an amenity, it is a treasure. It offers a necessity of life that must be rationed among those who have power over it." **** "The different traditions and practices in different parts of the country may lead to varying results, but the effort always is to secure an equitable apportionment without quibbling over formulas."

"The governing rule is that this Court will not exert its extraordinary power to control the conduct of one state at the suit of another, unless the threatened invasion of rights is of serious magnitude and established by clear and convincing evidence."

"The diversion herein allowed shall not constitute a prior appropriation and shall not give the State of New York and the City of New York any superiority of right over the State of New Jersey and the Commonwealth of Pennsylvania in the enjoyment and use of the Delaware River and its tributaries."

"The removal of water to a different watershed obviously must be allowed at times unless states are to be deprived of the most beneficial use on formal grounds."

HAROLD CONKLING:[1] On May 4, 1931, after the foregoing was written, the Supreme Court of the United States decided the case of New Jersey v. New York, 256, U. S. 296. This is ably summarized and discussed by Nathan B. Jacobs in his discussion of the paper. This decision apparently coincides closely with the principles laid down in the various compacts noted in the foregoing paper and allocates the water of the Delaware River equitably to the three states interested, without regard to priority of right. This decision also allows payment in kind for damages to New Jersey by the proposed diversions in New York state. This payment in kind is to be brought about by substantial release of stored water into the stream to augment low flows.

On August 31, 1931, the Supreme Court of California decided the case of Collier v. Merced Irrigation District, 82 Cal. 351. This was an action for damages caused to a riparian owner by construction of an impounding reservoir above. In the decision the benefits of release of water agreed to by the defendant was judged to offset damages to the plaintiff and no award was allowed.

It would appear from the foregoing that public necessity is causing the courts to modify the basic tenets of both the appropriative and riparian doctrines of water rights. In other words, limitations to their applicability are recognized in the first case cited and in both cases the mechanics of condemnation are helped by recognition of the benefits brought about by payment in kind.

THE COLORADO RIVER AQUEDUCT FOR SUPPLYING WATER TO SOUTHERN CALIFORNIA

By Julian Hinds[1]

The purpose of the following paper is to summarize the relation of the Hoover dam, now under construction by the United States Bureau of Reclamation, to the water supply problems of the Pacific slope of Southern California and to indicate in a general way the steps being taken to make a portion of the waters of the Colorado River, conserved by this dam, available to Los Angeles and her sister cities of the Southwest.

THE COLORADO RIVER

Now that the construction of the Hoover dam is actually under way, the problem of the Colorado River and its utilization has been advanced one step nearer an ultimate solution. This river drains an area of some 240,000 square miles, or one-twelfth of the area of continental United States, extending from the snow-capped mountains of Colorado, Wyoming and Utah, to the desolate regions of northern Mexico. Precipitation capable of supporting a dependable river discharge occurs principally in the high mountain areas. The lower portions of the watershed vary from semi-arid to desert conditions. Much of the region is rugged and unsuited to intensive development. However, there exist numerous extensive areas of tillable lands possessing great fertility, climatic advantages favorable to the production of high priced crops, and other attributes fitting them for useful development. In all this region water is the limiting element. The Colorado River, when properly controlled, will relieve this limitation, at least in part, and is thus destined to play an important rôle in the future development of the basin.

The relation of the Colorado River basin to the area of the United States is shown on figure 1. The drainage area, to a larger scale, with approximate isohyetal lines, is shown on figure 2.

In common with all streams of the West, the flow of the Colorado

[1] Designing Engineer, Metropolitan Water District of Southern California, Los Angeles, Calif.

FIG. 1. RELATION OF COLORADO RIVER BASIN TO AREA OF UNITED STATES

varies through wide limits. It is estimated that the mean annual discharge over a long period past the Hoover dam site is approximately 22,000 cubic feet per second. During the periods of low flow only a small part of this average can be depended upon, a discharge

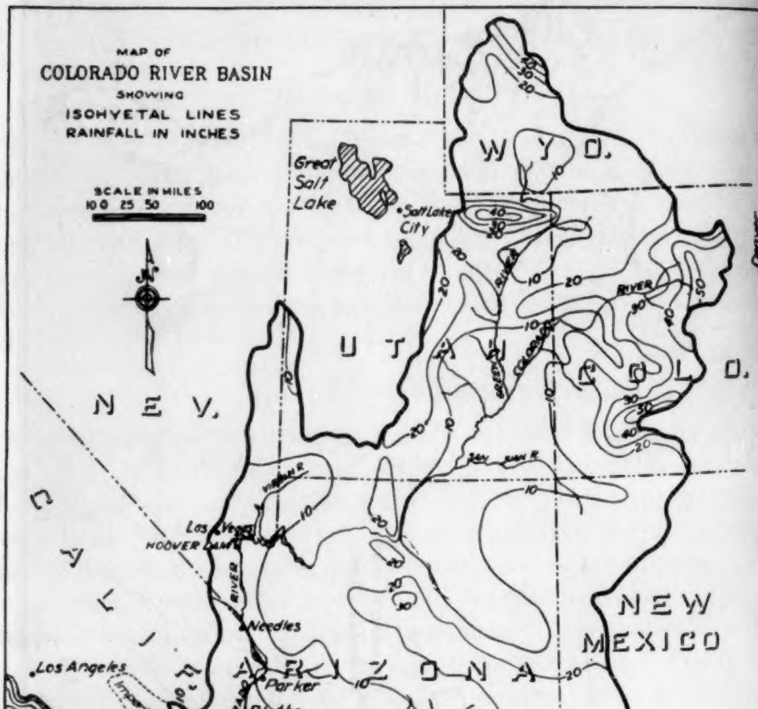

FIG. 2. DRAINAGE AREA TO LARGER SCALE WITH ISOHYETAL LINES

of 5,500 second feet being a reasonable average at low stage. This low flow has been almost fully absorbed by irrigation development along the lower river in California, Arizona, and the Republic of Mexico. No further development is possible without the equalization of flow by storage.

The Hoover dam, creating a storage space of 30,500,000 acre feet, is proposed as a means of regulating the flow, both to make it available for beneficial use and to afford protection against floods. Inci-

FIG. 3. SITE OF HOOVER DAM IN BLACK CANYON
(Copyright-Jno. P. Commons)

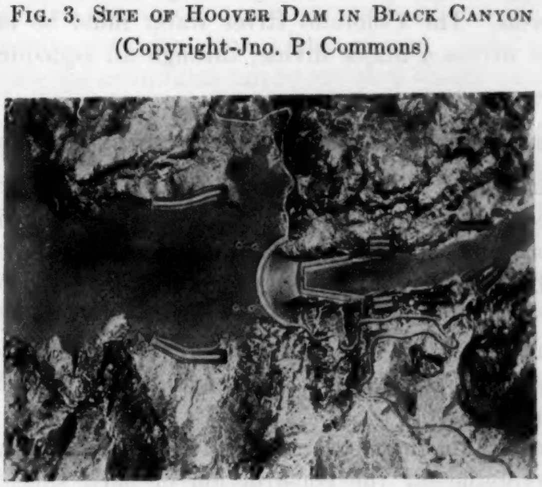

FIG. 4. ARTIST'S CONCEPTION OF COMPLETED DAM

dentally, it will release a large block of power, badly needed to support the industrial development of the Southwest. With this reservoir in operation, the dependable flow of the river will be greatly augmented, making it possible to supply water to a largely increased

population. Los Angeles and her sister cities hope to secure a portion of this increased flow for a domestic supply and to accomplish this purpose have formed a confederation, known as "The Metropolitan Water District of Southern California."

Figure 3 is a view looking downstream into the canyon near the dam site. Figure 4 is an artist's conception of how the dam will appear from the air after it is completed.

THE METROPOLITAN WATER DISTRICT

The District at present (Sept., 1931) is composed of 13 cities with a combined population of 1,666,000 and an assessed valuation of $240,000,000. Other cities are expected to join. The District was organized for the specific purpose of importing water from the Colorado River and at present has no other purpose. The plans contemplate the diversion of a continuous flow of 1500 second feet which, after deducting for losses in transit, will almost double the present water supply.

The cities of the District are not within the Colorado River watershed, but are situated in what is generally referred to as the South Coastal Basin. The Colorado River water must be brought into the District across a major divide, through an aqueduct some 250 miles long.

NATURE OF THE AREA TO BE TRAVERSED BY THE AQUEDUCT

The entire region between the river and the metropolitan basin is very rugged and the geology is complex. The region is composed generally of barren mountains, separated by deep valleys filled with porous debris. Some of these gravel-filled pockets, of unknown depth, have no outlets and have accumulated the scanty rainfall of past ages until they are now full of water. They are serious barriers against deep tunnels, as are the numerous faults and fissures which traverse the area.

Surface conditions in the detrital materials vary widely but generally are favorable for the construction of lined surface conduits. The mountain areas above the detrital cones are usually rugged and unsuited to surface conduit construction.

THE NECESSITY FOR A PUMPING PROJECT

The air line distance from Los Angeles to the river is more or less constant all the way from Yuma to the Hoover dam site. The river

bed elevation in this distance varies from about 120 feet to 600 feet above sea level. The area to be supplied from the aqueduct varies from sea level to an elevation of 1500 feet with limited areas even higher. Assuming that the major portions of the highest areas can be supplied from present high level sources, a fairly large percentage of the Colorado River water may be allocated to areas below elevation 500 feet. But even this level is higher than the bed of the river at most of the possible diversion points. Furthermore, a fall of approximately 1,000 feet is required to overcome friction in the aqueduct and distributing lines. It is therefore necessary that the water be pumped or elevated by some means at least sufficiently to overcome friction losses.

The District area also is separated from the Colorado River watershed by high plateaus and mountain ranges To tunnel entirely through these high areas, at the minimum level required for the delivery of water, would be enormously expensive even if feasible. Actually, such a tunnel would be impossible of construction because of geological difficulties. The water must therefore be lifted an additional amount over the minimum requirement for delivery, to avoid expensive construction, the proper height of lift being found from economic considerations. Part of the energy required for pumping over the mountains can be recovered in fall after the summit is passed.

Certain so-called gravity routes have been studied in great detail but have not been found advantageous. They generally involve long extensions of the aqueduct, mostly in tunnel, and the construction of immensely high diversion dams. The energy theoretically saved by such lines is largely offset by power losses resulting from the diversion of flow from prospective power plants on the river. The increase in capital expenditures is out of all proportion to the possible savings.

POINT OF DIVERSION

The fact that a considerable portion of the river is at an approximately constant distance from the area to be served, permits considerable latitude in the selection of a diversion point. Prudence dictates that, other things being approximately equal, the diversion should be made where the river is confined between definite rock banks and where a diversion dam or other headworks can be constructed and maintained in operation with facility. In the absence

FIG. 5. HILLS IN COACHELLA VALLEY, SHOWING ROUGH PARTS OF AREA

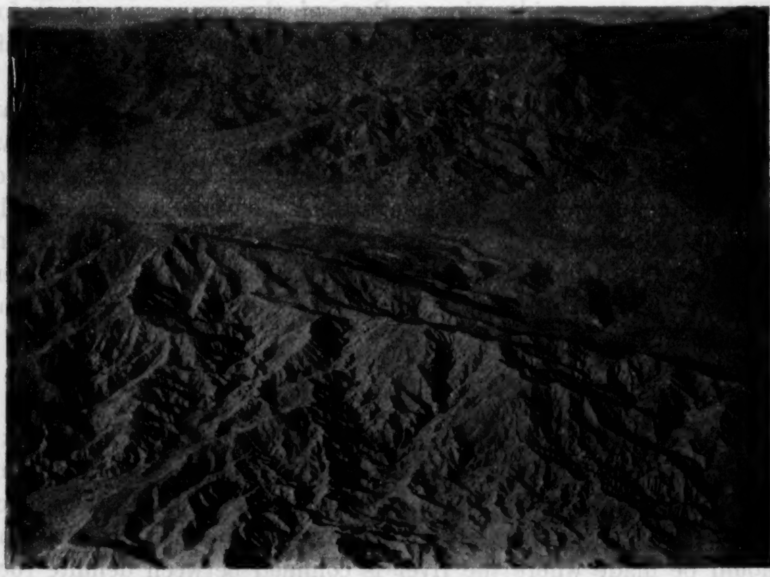

FIG. 6. AERIAL VIEW OF LITTLE SAN BERNARDINO MOUNTAINS ALONG PARKER LINE

FIG. 7. FOOTHILLS ALONG NORTH RIM OF IMPERIAL VALLEY

FIG. 8. SAN ANDREAS FAULT, COACHELLA VALLEY

Fig. 9. Surface Conduit Country at Hayfield Dry Lake

Fig. 10. From Hayfield Dry Lake toward Northeast

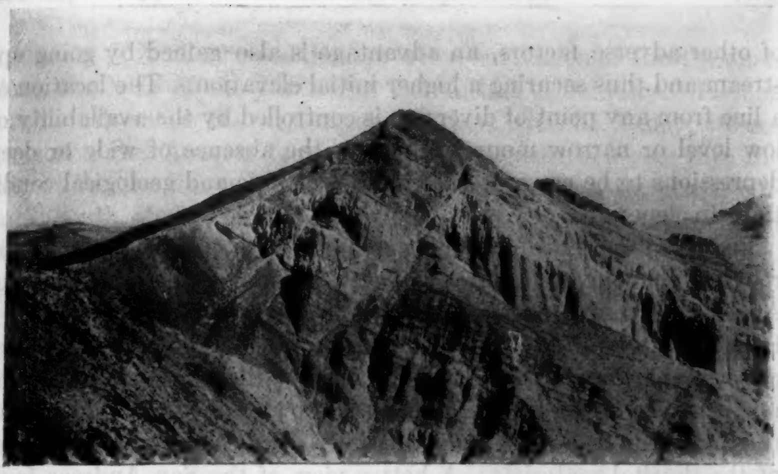

FIG. 11. GEOLOGICAL FAULTS NEAR HOOVER DAM

FIG. 12. AERIAL MAP FROM COLORADO RIVER TO COAST

of other adverse factors, an advantage is also gained by going upstream and thus securing a higher initial elevation. The location of a line from any point of diversion is controlled by the availability of low level or narrow mountain passes, the absence of wide or deep depressions to be crossed, and the topographic and geological conditions in general.

Figure 5 is a view of the hills north of Mecca, showing some of the rougher portions of the area between the Colorado River and Los Angeles. These areas are avoided wherever possible. Figure 6 is an aerial view of the base of the Little San Bernardino Mountains, close to the Parker line. A typical view of the foot hills along the northern rim of the Imperial Valley is shown in figure 7. A trace of the San Andreas fault is faintly visible. Note the glacial-like effect of the detrital materials. A better view of the San Andreas fault in the same region is shown in figure 8. Figure 9 shows a typical stretch of country for surface conduit location with the extinct Hayfield dry lake, which is proposed for a reservoir site, running through the center of the view. A vew looking from the Hayfield dry lake toward the northeast and shows typical surface conduit country is given in figure 10. A sample of complicated geology a short distance from the Hoover dam site is indicated in figure 11, while figure 12 is a photograph of a relief map of the area from the Colorado River to the coast and gives an idea of the roughness of the country.

Considering the fact that in the beginning there was no particularly definite indication where the line should be located, in an area of some 30,000 square miles of rugged and at that time largely unsurveyed desert country, it will be appreciated that the problem was complicated. In its solution, hundreds of lines have been projected and estimated and from the results the Parker dam site, a short distance upstream from Parker, Arizona, has been chosen as a point of diversion.

DESCRIPTION OF PARKER ROUTE

The locations of the various types of section are indicated by symbols on figure 13. The aqueduct leaves the river in a steep pressure line and then goes into a series of tunnels aggregating about 12 miles in length. Then it follows a long reach of canal, interrupted occasionally by short pipe lines and tunnels, to Shavers Summit, a controlling pass. West of this summit the topography is rough and for

a distance of some 40 miles the line is in a succession of short tunnels along the base of the Little San Bernardino Mountains. It then turns south across the western end of the Coachella Valley, crosses the active San Andreas fault on the surface and then goes into the longest and deepest tunnel of the line, under the San Jacinto Mountains, south of the San Gorgonio Pass. This pass marks the final divide between the Colorado River watershed and the Pacific slope.

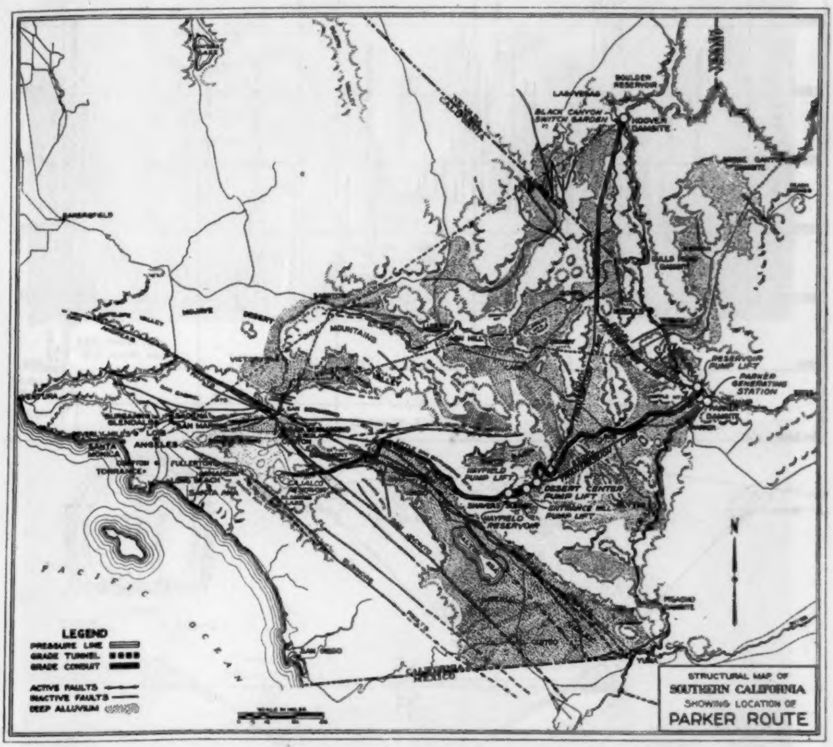

FIG. 13. PARKER ROUTE

The tunnel through it will be about 14 miles long and two intermediate construction shafts will be required to permit its construction within a reasonable time. West of this tunnel the line may proceed to the distribution center by either of several satisfactory routes.

The total length of the route, to the terminal reservoir, is 225.61 miles. Of this length, 57.81 miles will be lined canal, 60.77 miles cut and cover conduit, 84.17 miles tunnel, and 22.86 miles will be pressure lines, inverted siphons, etc.

The low water level in the Colorado River at Parker is 378 feet. It is proposed to raise this level by a concrete storage diversion dam to elevation 450 feet from which level it will be lifted 593 feet by

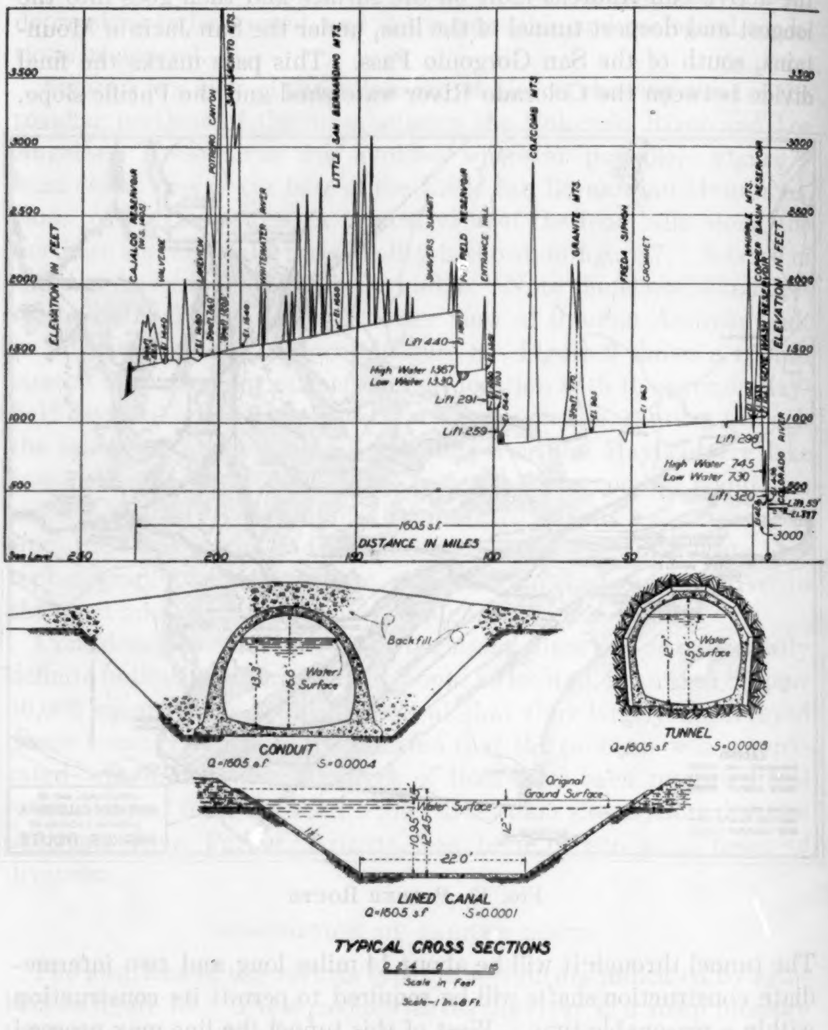

FIG. 14. PROFILE OF PARKER LINE

two pumping plants into the aqueduct at 1043 feet elevation. Two additional plants at mileposts 100 and 104 again lift the flow 550 feet and deliver it into the Hayfield reservoir at elevation 1367 feet.

The fifth and final lift of 440 feet takes the water from this reservoir and delivers it through the pass at Shavers Summit. The total

FIG. 15. SURVEYING PARTY CLEARING ROAD

FIG. 16. ENGINEERS' DESERT CAMP

pump lift is 1583 feet, unless the dam at Parker is omitted, in which case the total life is 1655 feet. The locations of the lifts are shown on figure 13, as is also the routing of the lines for transmitting power

FIG. 17. AERIAL VIEW OF COLORADO RIVER AT PARKER DAM SITE

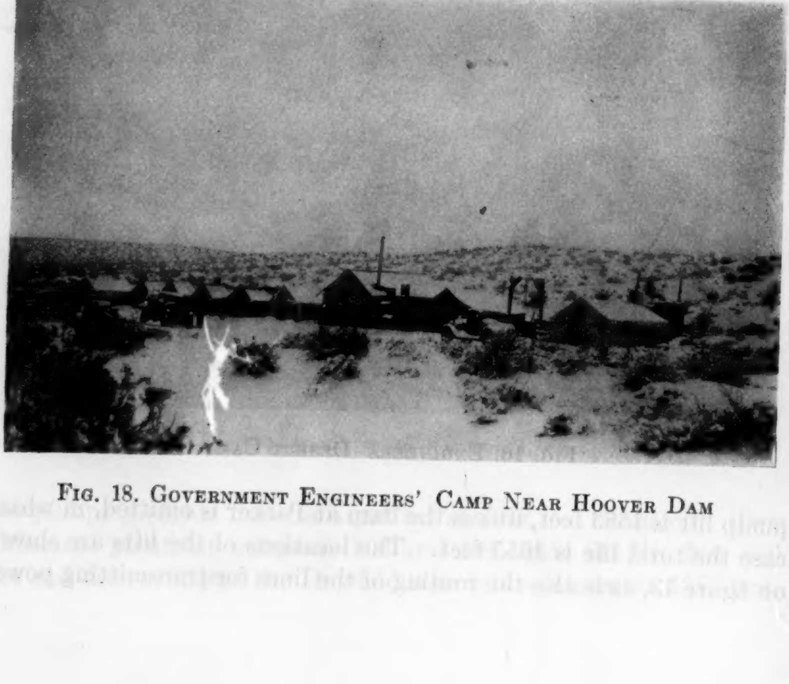

FIG. 18. GOVERNMENT ENGINEERS' CAMP NEAR HOOVER DAM

for pumping from the Hoover dam. The line as described and the figures given are from preliminary locations and subject to change.

A profile of the proposed Parker line is given in figure 14 and shows how the pumping plants are distributed along the route to secure at all points the most favorable construction conditions. Figure 15 shows a surveying party with a Ford station wagon clearing a road for themselves on the desert; 16, a view of a typical desert engineering camp; 17, an aerial view of the Colorado River at the Parker dam site, and 18 shows a winter scene in a surveyors' camp near the Hoover dam site.

TERMINAL FACILITIES

The locations shown for the aqueduct west of the San Jacinto Mountains are tentative and the locations of the return power drops have not been definitely decided upon. It is probable that a large amount of the flow can be dropped through a height of 400 feet or perhaps more. The flow to the coastal areas, which will no doubt be of considerable importance, may be dropped through 800 or 900 feet. The exact location of terminal storage reservoirs is likewise yet to be determined. Ample reservoir space can be developed at satisfactory locations. A storage capacity of 300,000 acre feet has been tentatively selected as sufficient for ultimate regulation and protection. Seasonal storage is available in the Boulder Canyon reservoir above the Hoover dam, local storage being required only to care for variations in demand and for protection against accidental interruption in service. The volume and distribution of storage will also have an important bearing on the value of the power producible at the drops on the aqueduct.

The District does not propose to make retail deliveries of water. The distribution system will consist simply of trunk lines supplying water to a convenient point at or near the boundary of each member city. Duplication of existing facilities is to be avoided wherever possible by exchange agreements, or by other means. When delivered to the individual cities the water will be mingled with the supplies from other sources and sold at retail to the individual users.

SOURCES OF POWER FOR PUMPING

Power for pumping will be secured from the plant to be constructed at Hoover dam. Contracts have been signed with the United States Government for 36 per cent of the firm power output of its proposed

plant at 1.63 mills per kw-hr., in the falling water. An additional charge charge will be made for generation, making the total cost something less than 2.0 mills. There will be available at times a considerable output of secondary power and the District has contracted for as much of such power as it may need, when available, at 0.5 mill per kw-hr. in the falling water, plus the cost of generation. The power plant will be constructed by the Government but will be leased for operation to the principal contractors for power. The District has no operating lease but will secure its power from the part of the plant leased to the City of Los Angeles. Under full development the five pumping plants on the Parker route will require 291,000 kw.

It is expected that the District will construct and operate a power plant at the Parker dam. It is possible to generate 80,000 kw. at this point, all of which may go to the District, unless the dam and generating plants are constructed as a joint enterprise, in which event the power output will probably be shared with other users. In the early years of operation the firm power contracted for at Hoover dam may be found sufficient to fully meet the District's demands, in which case it is possible that the construction of the Parker dam may be deferred for a time. Under such circumstance, deferment of the dam construction might have certain financial advantages, although these are largely offset by the cost of temporary pumping plants and clarification works required at the intake.

The power generated at Parker will be used there for pumping. Power produced at drops along the line may be used by the District for pumping in the aqueduct or distribution system, or it may be sold at wholesale, as may be found most advantageous. Provision will be made for producing such power at hours of peak demand, which is expected to add to its sale value.

Preliminary engineering work on this project is now nearing completion and final location of the main aqueduct is under way. The long tunnels, which are the controlling features as to length of the construction period, will be ready for construction by the time financial arrangements can be completed.

Investigation of the Colorado River project was begun by the Bureau of Water Works and Supply of the City of Los Angeles in 1923 and was carried on under the direction of Chief Engineer William Mulholland and his successor, H. A. Van Norman, until the spring of 1930 when it was taken over by the present District organization.

F. E. Weymouth is chief engineer of the District. W. P. Whitsett is chairman of the board of directors.

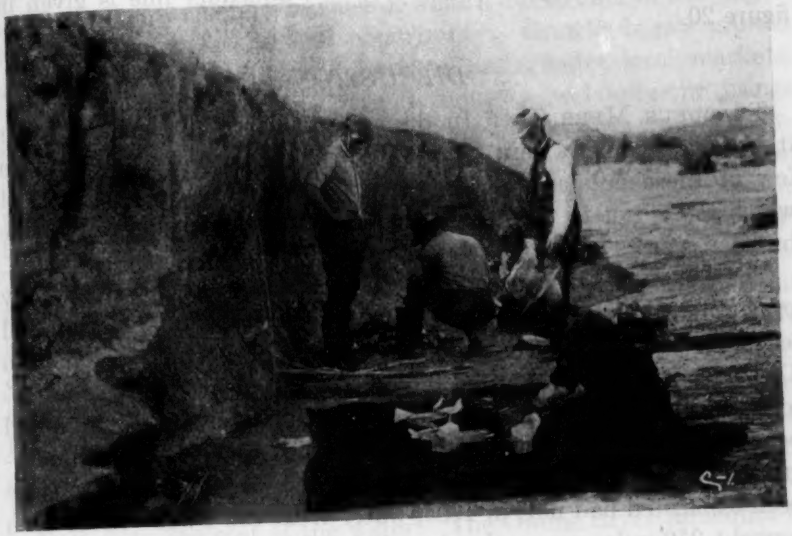

FIG. 19. RECONNAISSANCE SURVEY PARTY NOVEMBER, 1923

FIG. 20. F. E. WEYMOUTH, WILLIAM MULHOLLAND, AND W. P. WHITSETT

A photograph of William Mulholland and H. A. Van Norman preparing the first meal served on the Colorado River aqueduct

survey in November, 1923 is shown in figure 19. A photograph of F. E. Weymouth, William Mulholland, and W. P. Whitsett, on a recent inspection trip over the proposed aqueduct line is given in figure 20.

DISCUSSION

THADDEUS MERRIMAN:[2] In discussing this comprehensive paper it is only possible, within the allotted time, to direct attention to a few of those outstanding features of this great aqueduct project which relate not to the details of its engineering design but to the broader aspects of the enterprise.

The Colorado River Aqueduct is the most stupendous water supply project of all history. It appeals forcefully to the imagination and leads the mind to new concepts of magnitude. The Metropolitan District of California, located on the Pacific coastal plain, is far removed from any source of water except that which is to be found beneath the ground on which it stands. The capacity of these underground sources is necessarily limited, and they would have long since been exhausted had not, in 1905, water from the Owens River been brought 250 miles across the deserts for the use of the City of Los Angeles.

In 1900 the population of what is now known as the Metropolitan District was 220,000. By 1910 it had increased to 620,000. In 1905, when the City of Los Angeles set its hand to the Owens River project, it was an enormous undertaking for a city of 160,000 people. That project was conceived and carried to completion by the ingenuity and the resourcefulness of William Mulholland, whose name will always be remembered as that of the man who made Los Angeles great. The cost of the Owens River Aqueduct was $25,000,000, and it brought to the city about 400 cubic feet per second of water.

As is ever the case, there were then those who objected to going to the Owens River. At one of the meetings which was held, somebody arose while Mr. Mulholland was speaking and said that this water would never be needed. His answer simply was:—"Gentlemen, if you do not get this water you will never need it." Still did the district continue to grow. By 1920 its population was 1,600,000 and in 1930 it was 2,500,000. Never before in all history has there been so great a growth in any one locality.

[2] Chief Engineer, Board of Water Supply, New York, N. Y.

The basic reasons for this wonderful development are evident. Southern California has the natural inherent capacity of drawing people to its hearthstone because of what it has to offer in the way of climate, comfort, health and opportunity. Growth begets growth and growth means increased business and greater local markets. These conditions, in turn, attract industry and industry brings population in its train. Thus it is that Southern California is growing at the expense of all the rest of the United States, because men, women and even children everywhere have their eyes set on the Pacific slope and hope some day to be able to go there and to stay. This great growth, moreover, and for the reasons stated, seems destined to continue until the saturation point is reached. That point is clearly marked as the limit of the available water supplies. No community can develop or grow beyond its water developing capacity, and that is more true of Southern California than elsewhere because the natural state of much of the area is largely that of a desert and because of the high rate of evaporation which results from the low humidity which humanity craves and ever seeks to enjoy.

Now as to the cost of the water. The Owens River Aqueduct in 1905 represented a per capita investment of \$125. The corresponding figure for the Colorado River Aqueduct of 1931 will be less than \$100. The cost per capita on the basis of the present population will be close to two cents per day. Is that extravagance? I think not, because I know of no other fundamental commodity which costs so little. And neither is there any other which makes so largely for wealth and value as does water. Southern California owes her present greatness to the water of the Owens River. Her future is bound up in the water of the Colorado.

These waters she must have, else stagnation will be the inevitable result. The recent rates of growth indicate that the population of the Metropolitan District, by 1960, will reach, if not exceed, eight million, and even then there will be room for many more. The Colorado Aqueduct as now proposed will care for the water needs until 1960, about which time the District will undoubtedly once more be looking about for water to meet its needs and once again there will be the usual crop of pessimists who will say that more water will never be needed. The water works man, however, knows that all growth and development have their roots deep down in the water supply systems and that more population always means a greater need for water.

The Colorado River, on which the aqueduct now proposed will have its intake, is more than three hundred miles distant from the center of the district. It is as far away from Los Angeles as Fort Wayne, Indiana, is from Pittsburgh. It is as distant from Pittsburgh as Lancaster, Pennsylvania. It is twice as far as the City of New York must go for its water. Yet, the Colorado River is the only source of supply that is available, aside from a few small additions from the north which are now in the process of being developed. There is no alternative to the Colorado River, and between it and the District stretches a desert country that is bare, barren and desolate.

The Colorado Aqueduct will cross this desert where the sun ever shines and daily heats the rocks, so that the night may cool them off. Because of the consequent great temperature variations and the extreme dryness the rocks, many of which are similar to those of New England, break down into small stones and sand with surprising rapidity.

The Colorado River drains an area of 220,000 square miles, but on that area there are also many thousand more square miles of vertical surfaces. The wind always blowing, erodes all of these surfaces which are continually breaking down under the heat of the day and the coolness of the night, and so a great volume of silt is made available for all of the drainage channels to transport. The wind erodes the surfaces as by a sandblast and then carries its burden into the lower parts of the valleys where it waits for the first rain or the water of the melting snows to pick it up and carry it along.

The Colorado Aqueduct project is predicated directly on the Hoover Dam Development. Without the river regulation afforded by that development it would not be possible, while without the power generated at that dam it would hardly be practicable. The Metropolitan District will, of course, carry its share of the cost of the Hoover Dam, through the payments that will be made for the water that is stored behind it, as well as for the power that will be used in connection with the aqueduct pumping.

The construction cost for carrying water from the Colorado River into the district, but not including its delivery to the separate municipalities which comprise the district, will be close to two hundred million dollars. And this amount, as I have already pointed out, represents a per capita investment of less than \$100. What other form of investment could yield as much? The average man's per-

sonal equipment of clothing costs practically the same and must be almost completely renewed every year or two—while here is an investment the life of which is to be measured in hundreds of years, and the income from which is incalculable.

Time does not permit me to discuss this most interesting enterprise further. As I have said, it appeals to the imagination and is truly difficult of adequate description. And while this great Colorado River Aqueduct is indicative of progress, yet I trust that it does not point the way to too much of an advance in efficiency. Engineers are often prone to think of efficiency in terms of saving the immediate dollar and thus fail to give thought to the status of the ultimate dollar. No community, nor no nation, can ever reach the maximum of happiness and contentment unless there is plenty of work for all to do and every individual has his task to perform. In a world where everybody is employed the efficiency of competition will never have the important place to which it is now generally assigned. True efficiency pays dividends in contentment, while the profits of business are merely indications of the other man's losses.

MR. ETNER (Council Bluffs, Ia.): I do not quite understand how the sediment that accumulates behind the Boulder Dam will be gotten rid of.

MR. MERRIMAN: It must be remembered that Boulder Dam will form a great reservoir. The water coming into it will have much time to settle and thus all of its silt burden will be removed. No silt will pass either through the wheels of the power house below the dam, or over its spillway. But thereafter, in the river channel below, the water will pick up a new load of silt which will be deposited in the Parker reservoir above the aqueduct intake. Any silt that the water may contain after passing the Parker reservoir will be removed by the settling basins, or by clarifiers located near the intake.

The silt problem will always be present, but, under the plans, sedimentation is provided for in the settling basins at Parker, and again in Hayfield reservoir near the summit, from which the water will flow by gravity on its way toward the West.

CHAIRMAN MORSE: Are there any more questions?

MR. MERRIMAN: I might add to that that there will be still further opportunity for sedimentation in the terminal storage reservoirs and

it is to be noted also that the Colorado silt is not like much of that in our eastern waters. It is a silt which, in general, settles out rapidly and completely.

Mr. Spaulding: How about silt in the Hoover Reservoir?

Mr. Merriman: The best figures that have been made indicate that about one hundred and eighty years' time will be required before that reservoir will become filled with silt. The problem after that must be left for the engineer of the future.

Mr. Spaulding: I would like to ask another question. Is it expected that the water rates of Southern California will have to be materially increased on account of this new supply, or will they remain practically as they are now?

Mr. Merriman: I am not very familiar with the subject matter of this question, but I should say that the rates will probably not have to be greatly changed. This is not a purely domestic supply in that much water is used for irrigation purposes. A shortage of water in our Eastern states is not as serious a matter as it is in Southern California. During a shortage here it is often possible to get through by rationing the water that remains. None of our crops would suffer permanent injury because none are irrigated. In Southern California, however, serious permanent injury and loss would result to many of the agricultural interests as practically all of them are dependent on irrigation.

Mr. Spaulding: May I ask further whether this project has been actually started?

Mr. Merriman: The plans are practically ready and the election on the bond issue will be held in the near future.

Mr. Spaulding: How long is it anticipated it will take to finish the job?

Mr. Merriman: From six to seven years will see the aqueduct ready to deliver water. Not all of the pumping capacity will be installed at first. About one-third of the ultimate pumping equipment will be included in the initial installation.

Mr. Day (St. Louis, Mo.): How many pumping stages are there on this aqueduct?

Mr. Merriman: My recollection is that there will be six, with one power return plant where a drop of 400 feet can be utilized. The first lift out of the Colorado River is comparatively small, because the preliminary clarifiers will be located there. The total pump lift for the project as a whole is 1600 feet.

Mr. Spaulding: What is the approximate horse power that this four hundred foot drop will give?

Mr. Merriman: My best recollection is that the return horse power will be close to 50,000.

THE 1930 DROUGHT AND ITS LESSONS

F. R. Berry:[1] For the thirty years that I have been in the water works business no drought has occurred that has been given such wide publicity as the drought of 1930. In certain limited sections, Kansas for example, there have been a number of summers during the last twenty-five years when the rainfall was less than it was in 1930, but taking the country as a whole, the 1930 drought was more severe than any within my experience. In many sections of the country, not only were public water supplies seriously affected, but also crops, wild game life, and even navigation. In many small communities, water necessary to maintain life was hauled in tank cars and in trucks. In many municipalities large as well as small restrictions on the use of water were necessary, and in some cases have not yet been entirely removed. In the case of municipally owned water works plants such restrictions could be, and generally were, enforced by the Police Department. Where communities were served by privately owned water companies restrictions curtailing sprinkling, pavement and automobile washing, could not be enforced in this manner, but it was very gratifying that in the few instances in the group of water properties with which I am associated, where curtailment in the use of water seemed advisable, the consumers responded generously to notices in the public press. The public, in general, seemed to be impressed, perhaps being influenced by the front page newspaper drought items, and realizing the severity and extent of the area affected by the unprecedented drought, coöperated to the fullest extent to conserve the dwindling water supplies, in every way fulfilling the traditions of the American public in times of National disaster.

While the deficiency in rainfall for the calendar year 1930 over the entire country was only 13 percent below normal, there were only five states in the entire country, namely, Arizona, Colorado, New Mexico, Utah and Wyoming, where the rainfall was in excess of normal for the summer months of June, July and August. The population of these five states is only a small percentage of the popu-

[1] Engineer, American Water Works and Electric Company, New York, N. Y.

lation of the United States, therefore, a very large proportion of the population of the country was affected to a greater or less extent by the drought.

The fact that there was such a great deficiency during the summer months accentuated very appreciably the suffering, and also resulted in an unusual increase in the demands on the water works systems of the United States.

Subsidiary water companies of the American Water Work and Electric Company operate in thirteen of the states, all or part of which have been considered as included in the drought area of 1930. These states are: Arkansas, Connecticut, Illinois, Indiana, Iowa, Missouri, New Jersey, Ohio, Pennsylvania, Tennessee, West Virginia, Virginia and Wisconsin.

At some of the plants in some of these states the industrial consumption is an appreciable part of the total demand, and on account of the business depression the use of water by the industries had decreased to such an extent that the total demand was not increased over some preceding years, notwithstanding the fact that the domestic consumption was substantially increased.

I have taken four plants as examples to show the effect of the drought and hot weather of 1930 on the consumption of water as compared with the previous year, and in none of these plants is the industrial consumption a material factor.

The Commonwealth Water Company supplies water to a large suburban district in northern New Jersey within commuting distance of New York City. During the month of maximum consumption the total pumpage increased 8.3 percent; the maximum days consumption was 18.5 percent higher than any previous record, although the number of consumers increased only 3.6 percent.

The Huntington Water Corporation supplies water to the City of Huntington, West Virginia, and some outlying territory. The maximum month's pumpage was 15.1 percent higher, and the maximum day's pumpage 12.1 percent higher than any previous record, although the number of consumers had decreased 1.4 percent as compared with 1929.

The South Pittsburgh Water Company supplies water to a part of Pittsburgh, Pa., and a number of boroughs and townships on the hills south of the Monongahela River. During the summer of 1930 the maximum month's pumpage was 13.6 percent, the maximum day's pumpage 14.2 percent, and the maximum rate 27 percent

higher than the previous record which was in 1929. The number of consumers in 1930 had increased only 5.8 percent over the preceding year.

The Wichita Water Company supplies water to the City of Wichita, Kansas, and while Kansas was not considered as one of the drought states the normal annual rainfall is only 26.8 inches. It might, therefore, be considered as a perpetually dry state, and on account of the excessively hot weather during the summer of 1930 the maximum month's pumpage was 34.5 percent, and the maximum day's pumpage 32.8 percent higher than any previous record. The number of consumers had increased only 0.5 percent from 1929.

NEED FOR REAPPRAISING CUSTOMARY DESIGN ASSUMPTIONS

It has been the practice of the Company with which I am associated to estimate future requirements from a consideration of the past increase in consumption for the maximum hour, day, week, or month, depending on whether or not the plant is a direct pumping plant, and on the amount of water, if any, contained in the elevated storage tanks or reservoirs. Unless the rate of pumpage from year to year is influenced by the addition or loss of one or more large industrial consumers, experience shows that the consumption follows very closely the increase in the number of consumers. It is readily understandable, therefore, that an increase in consumption of as much as 27 percent in 1930 over the previous high record as was experienced at the plant of the South Pittsburgh Water Company with a normal annual increase of only about 6 percent that the facilities for delivering and distributing water during the periods of peak consumption were somewhat inadequate. It is not usual in our practice to anticipate the future for more than five or ten years, and it follows, therefore, that at the South Pittsburgh Water Company plant in 1930 a rate of consumption was reached that under normal conditions, based on past experience, would not have been reached for some four or five years in the future.

The question of economics necessarily enters into a consideration of how much weight should be given to providing facilities to afford 100 percent service to meet maximum demands for only a few hours or a few days resulting from an unprecedented drought like 1930.

Assume a water works plant furnishing service to a community that has shown but little, if any growth in population during the past five to ten years. Assume further that the service in 1930 to some consumers was inadequate or perhaps entirely lacking for a few hours a day not to exceed eight or ten days.

Should a water company under such conditions expend a substantial amount of money to rectify this condition? Such an expenditure, if the plant was earning only a fair return on its present value, would necessitate an increase in rates under State regulation. It is my conviction that, where extremely high rates of consumption are brought about by unprecedented climatic conditions, possibly non-recurring for the next generation, such an expenditure is not justified. To provide facilities to meet a drought condition which, in the case of one of the subsidiaries of the American Water Works and Electric Company, has occurred only once in the last 105 years, might, and probably would, involve what might be reasonably considered an overbuilt plant. It is certain that in any rate proceeding a plant built to meet a condition that occurs only once in 100 years might well be considered too large for the reasonable future, and the value of the rate base reduced by such excess capacity.

I cannot help but feel that the extremely high pumpages and the reduction in the available water supplies resulting from the drought of 1930, where such lack of rainfall and excess temperatures have occurred only in extremely long intervals, such as a generation, that the basic designs for the future, based on average past increases in consumption, should not be greatly modified. It is much saner, in my opinion, to have to curtail lawn sprinkling for a short period once every 25 years or so than it is to burden the water consumers with a rate for water to be paid every year so that perhaps four times in a century lawns can be watered without restriction.

NEED FOR BETTER RECORDS OF RAINFALL AND STREAM FLOW AS A BASIS FOR FORECASTING WATERSHED YIELDS

The U. S. Geological Survey in coöperation with designated Boards in a number of states, is obtaining information in reference to the flow of streams in representative sections of such states. It is true that this information has not been collected over any great length of time as the need for such was not until recently appreciated. The longer these records are collected the more valuable they become. The average small water company does not have the facilities or resources intelligently to collect, compile and interpret information of this kind. We have found in our experience that the U. S. Geological Survey, in coöperation with the states, are very coöperative and glad to furnish such information as is available and are also willing to install the necessary apparatus to obtain desired informa-

tion of stream flow and rainfall in sections of interest to water companies. The expense of such installation is usually borne jointly by such water company and the governmental boards. It is obvious that additional data can only be collected after a long period of time and in such locations as additional information is needed. It is the writer's view that it can best be obtained in coöperation with the U. S. Geological Survey and the properly designated State Boards.

Take the State of Virginia, as an example. Any record of runoffs in the vicinity of Alexandria would have been of little value in the year 1930. Impounded supplies designed for the driest year in the vicinity of Alexandria, Virginia, based on any record for the past 100 years, would have been inadequate during the year 1930 when streams having a watershed as large as 18 square miles went entirely dry and stayed dry for a period of several successive weeks.

EFFECT OF DROUGHT ON WATER QUALITY

With the reduced flow in the streams caused by the drought, many purification problems became more difficult and new ones developed. Among these were the increased effect of industrial wastes and pollution from sewage, to the point where it became impossible by the ordinary methods of water purification to remove these substances, which created objectionable tastes and odors in the water. Odors and tastes from industrial wastes became more pronounced and became more difficult to eliminate with the reduced dilution afforded. Algae growths were accelerated in reservoirs because of the lack of runoff resulting in lessened turbidity. In a great many cases these algae growths decayed and when the first light rains came following the drought the taste and odor troubles were aggravated by the presence of decomposed organic matter from the dead algae. In the case of some streams receiving tannery wastes, the concentration of these wastes became so great as to give colors in the raw water which could not be entirely removed.

In the case of some streams which received mine drainage, such as the Monongahela River, during the extreme low flow caused by the drought the concentration of acidity became greater than any previous record. This high acidity caused a great deal of trouble in the purification plants. When sufficient lime was added to neutralize the acidity, the mass of floc formed was greater than could be handled with the facilities ordinarily adequate. Severe taste and odor troubles also occurred in the Monongahela River due to the fact

that the storage in Lake Lynn was used to maintain a navigable stage of the river. The storage in Lake Lynn was filled with algae grows, and when this water was allowed to mingle with the acid river, the algae were killed, resulting in an intensive odor from this decayed plant life.

Algae growths in impounded supplies were greatly aggravated on account of the long, dry, hot summer season.

As would be expected, the lack of rainfall very materially increased the hardness of all flowing streams. The expense of softening water, where the public water supply is softened, was enormously increased. On the lower reaches of the Monongahela River, and perhaps some other streams, the acidity of the entire stream was neutralized by the industries using water for industrial purposes. This condition seriously affected the operation of softening plants using such sources of supply.

The flow of the Appomattox River became so low that the high tides carried the salt water to a point many miles above any previous record, resulting in a high temporary chloride content of public water supplies taken from this stream at points below. Hopewell, Virginia, is one of the municipalities whose supply is obtained from this source and which was so affected.

All of the usual preventives for eliminating these tastes and odors were used, and in addition, powdered activated carbon was introduced into the water at a number of the water plants with which I am connected, with fairly satisfactory results, although, even with the activated carbon treatment, it was not possible to eliminate entirely all objectionable tastes and odors continuously.

It is only fair to state that, in our experience, while the activated carbon treatment at times did not entirely eliminate all of the tastes and odors prevalent in the raw water, it did greatly reduce them, and probably if the plants had been better equipped for adopting this treatment it might well have been even more effective.

EMERGENCY WATER RELIEF MEASURES DURING DROUGHT

The means adopted during the drought of last year taxed the ingenuity and ability of the engineers of the various water companies affected to provide emergency measures to relieve the conditions which existed. Each plant presented a problem in itself, the problem, of course, being based on local conditions.

At the plants operated by the American Water Works and Electric

Company troubles were experienced at a few locations. At one plant we found a stream located about 3000 feet away with a flow sufficient to make up the deficiency. By strenuous efforts we located in the stock of a dealer of second hand machinery equipment which was trucked to a site which had been selected. We found a sufficient amount of pipe at a plant some forty or fifty miles distant, and within a very few days the equipment was in operation and the emergency had been taken care of.

At another plant where the main supply was obtained from infiltration galleries extending parallel with the bed of a small stream, a temporary sandbag dam was constructed across the stream, raising the head of water on the gallery, and the supply increased sufficiently to meet the demands, and at another plant there was found available in the district a well at an ice plant which was not used. Temporary equipment was provided for pumping this supply into the distribution system. Of course, in each case the approval of the State Board of Health was obtained before the water was used. No doubt many other expedients were adopted and a discussion of the experiences of other plants would be very interesting and helpful to all water works operators where operations are conducted in districts subject to a shortage in the water supply.

Reeves J. Newsom:[2] A good many of you probably remember the discussion about education that takes place in the early chapters of "Alice in Wonderland." I think the gryphon was talking about history and Alice said: "This is the driest thing I know." Quite obviously this was written before the 1930 drought.

The drought of 1930 has been and, in some places still is, the worst of any of which we here in America have record.

During the year 1930 forty out of the forty-eight states had less than normal rainfall. Twenty established new low records for precipitation; Kentucky, West Virginia and Virginia were 20 to 23 percent below the previous low record; Maryland was 30 percent below the lowest in any year since the records have been established.

The trouble did not end with the beginning of 1931. Not until March of this year has there been a definite indication that the end was at hand.

Some historians have a theory that every great center of civiliza-

[2] Executive Vice-President, Community Water Service Company, New York, N. Y.

tion has gone through three climatic stages. First a rich productive period when natural weather conditions were good, rainfall sufficient, etc.; then an irrigation stage when human artifice was called upon to remedy the deficiencies of nature; and third, the desert stage, the coming of which not even human ingenuity could prevent. How much there is in the theory is hard to say.

Looking back into the past, however, it is curious to observe how many of the great empires we have located buried beneath desert sands. They are still digging out palaces and temples in the Sahara and in Mesopotamia. It is thought from Marco Polo's account of his travels when he crossed the Gobi Desert in 1260 that there he met the ruins of great empires.

As an example of the intermediate irrigation stage Spain would seem to serve. There have apparently been great changes in climatic conditions in the Iberian peninsular since the days when Spain was the greatest nation of the world.

As far back as we have any historical record we find mention of excessive rainfall and excessive drought, but, as it is only in recent years that there have been adequate methods of measuring both rainfall and deficiency of rainfall, comments of diarists and analysts are in most cases not of much value. All of the early chronicles, however, indicate that floods and droughts are not a modern discovery. It is recorded that in 1592 people could cross the Thames on horseback as far up the river as London Bridge. The Fugger news letters which went back and forth from England to the continent during the sixteenth century are full of mentions of—"prodigious floods"—"we have had no clear day for three months." Walpole writing from Strawberry Hill 100 years later humorously says—"Have had a great deal of weather—all bad."

In 1677 in the village of Townly, Lancashire, an attempt was made seriously to record rainfall, and from that time to this, with few intermissions, records have continued.

On the whole, flood conditions are better recorded than deficiencies of rainfall, although there would seem to be no reason to believe there have been any more of one than the other. A number of theories have been evolved about weather cycles. Francis Bacon believed in a theory that he reports came from Belgium, that there were cycles of 35 years. Others have discovered what would seem to be 11 year periods, and as yet there are no very strong items in favor of either.

Most of us who are in the water business have our minds pretty

full of new records for deficiency, and I shall not try to startle you with greater ones. But if there is anything in the cyclical theory that every dry spell is followed by a wet one, you may be somewhat cheered up to be reminded of some of the figures for record rainfalls which you can take as an indication of what is coming to us.

In Porto Bello, May 1, 1908 it rained 2½ inches in 3 minutes. In 1912 in the Phillipines they recorded 46 inches in one day.

While probably none of us are very anxious to see any more drought, on the other hand, I doubt if many of us feel competent to deal with 46 inches a day.

The 1930 drought has been bad news for all of us, but it has also been a lesson to us. We have discovered the inadequacy of appraisals of yield of our supply sources. In one of our companies at Canonsburg the yield per square mile of drainage basin established a new minimum record—it was zero. Examples of minimum stream flows established during the last year are too common to bear repeating. Up to last year I think most of us believed that there was something in the theory of rainfall cycles. 1930 has established the fact that very little was known about these cycles, not enough at least to help us to spot the lows before they reached us.

We have discovered that our factor of safety which we had allowed for run-off was inadequate. We knew a long drought would diminish it gradually. We have discovered in many cases it eliminated it entirely. We knew that streams and surface supplies would be the first to be affected, and that ground water sources would ultimately suffer. How much ground water sources have been depleted by the drought we do not know. Only now are the statistics beginning to be available. It is interesting to realize that what these statistics tell us will be *new* knowledge that has never served mankind before.

As a whole the country had a narrow escape in the 1930–31 drought. Vaguely we knew of the dangers of disease from water shortage. The drought of last year disclosed new dangers. The exposure to the air of parts of reservoirs ordinarily under water leads to pollution. The heavy rainfalls that in some districts followed the prolonged dry spell resulted in many places in this accumulated pollution being washed suddenly into the distribution system in plants not using filtration. In some districts the shortage meant turning to emergency supplies. It *must* have meant in some isolated cases using water of questionable safety. In spite of all this we have emerged from the 1930 drought with no serious outbreaks of water-borne disease.

We found last summer that the peak load from sprinkling in many places caused the failure of clear water storage and distribution to high points or suburban areas fell down.

From a financial point of view the drought, with other elements, has disclosed a new four-phased problem. Operating costs have increased from additional pumping and the purchase of more water. Additional capital costs have been incurred as a result of the necessity of adding equipment and developing new sources of supply. In raising this additional money we have met more trouble in the form of extraordinarily large fixed charges, due to the large discounts on securities sold caused by the present condition of the securities market. All this has come at a time when the depression has seriously curtailed industrial consumption.

Aside from these difficulties peculiar to water companies, the country as a whole, and nearly all separate communities, have suffered as a direct result of the dry spell. There have been tremendous losses in crops and in livestock. Manufacturing plants using large amounts of water have been forced to close, as a result of which, many people have been put out of work and industrial losses have resulted from the decreased production. Hydro-electric plants have been forced to close, which has meant loss of power. Vast sums of money have been expended in adoping emergency relief measures. Some cities have had to buy water in tank cars. The Lexington Water Company, one of our subsidiary companies, was forced to construct, a 7 mile pipe-line to the Kentucky River, together with a 9 mile electric transmission line and pump station at the base of a 400 foot cliff at a point where water varies 40 feet at various stages of the river. All of this construction had to be done within a period of 70 days.

One result has been a great centering of interest on our business—the water business. People have realized everywhere that it is an essential of all civilization and progress, that no city or community can grow faster than its water supply. As a result there is renewed interest in the whole field. New attention is being given to the analyses of conditions, the result of which should be to help us somewhat more accurately than in the past to estimate the future. It seems to me that this particular aspect of the situation presents great possibilities. One of these is that science in time may discover more accurately the relations between the sun spot cycles and the cycles of weather conditions.

The possibility of the relation of weather conditions in one part of the world with those of another is interesting, and probably it is important. The summer of 1929 in England was exceedingly dry. The following winter in France along the Mediterranean was exceptionally severe. Then the summer after came our drought. Is there some connection between the three? Does it all have some relation to the sun spot cycles?

In India where there is the greatest dependence on the part of the whole population on rainfall, a seasonal forecast has been made in the last few years which has become of great economic importance. In figuring whether a year will be normal or subnormal in precipitation the Indian meteorologists have not only correlated the rainfall of India with the snowfall of the Himalayas, but with the atmospheric pressure of the southern hemisphere and over the Pacific, and with the rainfall in parts of Africa. They have been fairly successful.

If science learns how to warn us in advance of the coming conditions like those with which we confronted last summer, an inestimable benefit will have been conferred on us all.

Books and articles that have appeared within the last few months indicate the increase in interest that is already under way from the academic and theoretical point of view. Valuable work is being done on the subject of penetration of water into the soil as determined by soil moisture tests and by comparison with mountain run-off. Forecasts of precipitation, run-off and water flows are being prepared in a number of different parts of the country.

After new run-off and precipitation data are collected, and new design bases are available there will still be left a matter of policy which will have to be decided in each individual case. That problem is whether a plant should be designed for the maximum drought conditions we know of, which would, of course, necessitate excess rates for the intervening years when the rainfalls were normal, or whether our plants should be constructed to cope with what, to the best of our knowledge, would seem to be only reasonably in excess of normal conditions, with the prospect that at rare and infrequent intervals the community may have to suffer a curtailment in its use of water for a short time; or perhaps the prospect of extraordinary and excessive expense to develop emergency supplies. This is a difficult problem. The solution of it by one generation will, no doubt, be criticized by the next, whichever policy is followed. These are interesting problems that most of us are going to have to face.

From a practical operating point of view we are preparing, and I think with renewed assurance, tremendous projects to increase further the supply sources of our great cities. A 10-mile tunnel from Spring Wells to the Detroit River is being constructed to augment the supply of the City of Detroit. Boston is diverting the Ware River into the 15 mile Wachuset-Cold Brook Tunnel. In New York 500 feet below street level a gigantic aqueduct is being constructed from Yonkers to Brooklyn, passing under railways and subways, under tall buildings, under even the East River at Rikers Island. These are developments that would stagger the ancient Romans if they could know of them.

Before the 1930 drought there was on the part of the public a lack of interest in such projects, perhaps even doubt as to the wisdom of undertaking them. I think that doubt has disappeared.

Phases of the industry that a few years ago would have engaged the attention of only a few scientific minded cranks, or a group of more or less looked-down-upon technical experts like us who are here now, command today wide-spread attention and interest.

The problems that are to be discussed in this symposium cover such phases as I have referred to, and their mere discussion indicates that foundations are being laid to change the internal conditions of the industry so that we can face the next drought—for there always is another—better prepared than we were for the last one.

Here in the next hour or so will be presented to all of us the chance to capitalize our own experience and that of our colleagues and friends during the last trying year. It is rather doubtful whether we shall succeed in satisfactorily settling all of these problems, but I think at least we shall have taken another step to remove ourselves from the situation of the English schoolboy, who, confronted with the question on an examination paper as to what a drought was, wrote: "The drought, as I understand it, is not very well understood."

Paul Hansen:[3] Mr. Berry and Mr. Newsom deserve the thanks of the Association for a remarkably complete and concise review of the effects of the drought of 1930 on public water supplies.

Mr. Berry's principal thesis is that it is impractical to design and build water works prepared to meet the demands of drought which may occur once in 25 to 100 years. He leaves somewhat vague, how-

[3] Consulting Engineer, Chicago, Ill.

ever, the answer to the question as to what constitutes rational design to meet drought demands. Naturally, this is a very difficult question to answer. Certainly it cannot be answered in a few words. One difficulty in giving an answer is that water works consist of component parts each of which has to be considered somewhat differently with reference to adequacy in meeting unusual demands. In other words, water works do not constitute a single unit with a definitely limited capacity for furnishing water.

The principal elements of a modern water works are: (1) source of supply, (2) purification works, (3) pumping equipment, (4) distribution system, including equalizing reservoirs.

In considering any one of these elements with reference to capacity, a variety of factors enter, which are apt to differ for each one of the elements. Some of these factors are available funds, method of financing, rate of growth of the community, variations in rates of water consumption, life of structures, and ease or difficulty in augmenting structures. A mere statement of these factors makes it apparent that no criterion can be applied to a water works as a whole with reference to meeting drought conditions. A clearer conception of water works capacity for meeting drought conditions can best be had by considering each of the above elements along.

SOURCE OF SUPPLY

Public water supply is so essential to modern cities that there must be absolutely no complete failure of the source of supply in large cities (say over 25,000 population). In small communities it may be feasible to meet an emergency by hauling water into a city by railroad and other means, but, of course, this is very far from desirable. How much restriction can be placed upon the consumption of water during drought is difficult to state. The larger the city the less the practicability of applying restrictions.

Many cities are fortunate in having a virtually unlimited supply of water such as those that take their supplies from large rivers and the Great Lakes. Other cities are so situated that they must rely upon water from impounding reservoirs or wells. In developing an impounded supply the probable yield in a dry year is very pertinent. This is a matter that cannot be estimated with precision. Accordingly a rather liberal basis of design is required. Inasmuch as dams for impounding water are permanent and costly structures they are predicated upon the requirements of a good many years in the future.

If good records are kept for the purpose of determining the actual yield of such impounding reservoirs, and if such yield is related to other stream flow records and rainfall, a community can with reasonable definiteness determine when additional works should be installed. There is always a temptation to gamble that a year will be wet when it is known that the water consumption is close to or even more than a dry year yield of the development. This is unwise and even reprehensible. Perhaps the most excusable failures of sources during periods of drought are in the cases of unimpounded streams that have never previously had a natural flow approaching inadequacy. A few such cases occurred during the 1930 drought.

The yield of a well water supply during periods of drought cannot be determined with the degree of assurance that the yield of a surface water development can be determined. Well supplies have some advantage, however, over surface supplies in that additional wells may be quickly sunk and equipped in time of drought, providing the ground water supply is not actually exhausted. In connection with well water supplies the ground water condition should be watched and studied very carefully so that a new supply may be developed well in advance of the probable exhaustion of ground water resources.

Sometimes intake works in connection with a practically inexhaustible water supply may constitute a bottleneck in the system during periods of unusual demand such as occur during severe drought. This is rare, however, and little excuse exists for not anticipating intake limitations because these as a rule involve very little additional expense to secure liberal capacity.

PURIFICATION WORKS

Purification works are apt to constitute the most rigid bottleneck in a water works system during periods of excessive demand incident to droughts. This is because filters ordinarily can be operated for only a few days at as much as 50 per cent above their rated capacity. Furthermore, filters are seldom provided with by-passes nor is this permissible, especially if the raw water is seriously polluted. On top of this there is an unfortunate tendency to design filter plants on a rather restricted basis. Accordingly in water supply developments such as those existing along the shores of the Great Lakes the filter capacity is likely to prove the main restriction in delivering a sufficient quantity of water to a community.

With reasonable foresight it is generally possible to keep the

filters of adequate capacity to meet even drought demands without excessive investment, because after all, as indicated in Mr. Berry's paper, drought requirements will usually not exceed 25 percent of the daily demand of a normal year. Filter plants should, therefore, only be taxed beyond normal capacity during the last few years of the period for which they are designed to meet requirements. The first year during which filters must operate above normal capacity constitutes ample warning of the need of additional filters.

Strain on filter capacity can be greatly lessened by liberal filtered water storage, preferably elevated storage where this is practicable. Such storage also has other advantages in connection with pumping economy and distribution.

PUMPING EQUIPMENT

Drought conditions rarely overtax pumping equipment. This is due to three reasons:

1. There must always be standby equipment in case of breakdown. Standby units are available during drought conditions and can usually be kept in operation until new pumps can be installed.
2. There must be ample capacity to meet fire demands.
3. Electrically driven centrifugal pumps now commonly used are relatively cheap and can be quickly installed.

The net result is that most water works have a reasonable surplus of pumping equipment capable of meeting almost any demand likely to occur during severe drought.

DISTRIBUTION SYSTEM

During the 1930 drought the distribution systems of water works especially in residential communities with heavy lawn sprinkling loads have proven of insufficient capacity. This has resulted in low pressures and sometimes negative pressures in mains, even when there was an ample supply of water at the source and ample pumping equipment. Many of these limitations of the distribution system could easily have been anticipated as most of them were revealed at one time or another during periods of fire. They might also have been known and in some cases were known as a result of intelligent examinations of the distribution systems. In many cases distribution systems are extended in rather haphazard manner with the result that there do not exist well constituted systems of trunk mains. In short, it may be stated that, without excessive investment over that

required to give proper fire protection, a distribution system can be made adequate to supply reasonable demands even during periods of drought when large quantities of water are used for lawn sprinkling. The behavior of the distribution system can be greatly improved and also pumping economy can be improved by judiciously located elevated storage. Generally speaking there is an economic balance that can be struck with a proper combination of pumps, distribution mains and elevated storage capable of giving fair pressure during drought demands, provided the water works can meet reasonable fire demands.

As pointed out by Mr. Berry, one of our greatest limitations in anticipating requirements during drought years with reference to impounded supplies is lack of stream flow measurements. Fortunately such records are accumulating, but there is still a relative dearth of data on runoff from small water sheds. As is well known most of the impounded supplies are developed on relatively small water sheds.

The question of meeting drought conditions is well worth future study. As Mr. Berry pointed out, it is probably true that it is impracticable to built water works that will meet the severest drought without some restrictions on consumption. On the other hand, it is not entirely clear that with foresight and without unwarranted investments, water works cannot be maintained so as to forestall a water famine.

N. T. Veatch, Jr.:[4] The preceding papers and discussions have covered a subject of immense importance to the water works profession. The vast extent of the area affected by the drought of 1930, together with resulting damage to crops, suffering and need experienced by inhabitants of the area affected, have given the matter a spectacular feature, which by its very nature may cause erroneous conclusions to be reached. This has been exemplified in the relief works which was considered even by those living in at least certain localities affected, to have been overdone. There is the same danger in the interpretation that may be placed on the effect of the drought on water works design.

A careful scrutiny of the articles appearing in the technical press, particularly the series of articles in Engineering News-Record, dis-

[4] Consulting Engineer, Kansas City, Mo.

closes the fact that generally speaking the most serious troubles from water shortage occurred in the smaller towns and villages, depending upon springs, small surface streams with little or no storage, and in some cases shallow wells, although a number of the larger systems had quite serious operating troubles, undoubtedly due to the drought.

The purpose of these papers and discussions is to determine what if any change should be made in water works design. There is ample proof of the intensity of the drought, and of serious troubles encountered at various points. However, these facts in themselves should not stampede us into assuming that radical changes should be made in the basic assumptions used in the best water works practice. Before assuming that changes are needed, the exact circumstances surrounding the different plants having trouble should be ascertained, and these data analyzed something as follows:

Was the plant, in the part or parts showing weakness, designed along lines of the present best known practice? If so, how near had the designed capacity been approached by the growth and demands of the city?

If the answer is in negative, no evidence would exist that existing practice was at fault. If the answer is yes, in a majority of plants, deficiencies should be ascertained, and our basic assumptions corrected accordingly.

Believing from experience and observation that plants having had proper engineering design, and which had not about reached, or passed, their designed capacity based on normal conditions, had been able to meet the situation during the drought, by calling upon the factors of safety afforded by present design assumptions, an effort was made to ascertain if possible whether such a belief was well founded. Letters were sent out to a number of the principal plants, and something over sixty replies were received from plants in areas affected by the drought. Quite a number of plants in the areas most affected, were able to get by without any curtailment of service. Very few had trouble from lack of capacity in pumping or purification plants. Quite a number reported deficient pressures in certain areas, but, in a good many cases, stated that these deficiencies were known to exist before the drought. There were some that reported trouble from lack of supply, but this number was surprisingly small. The inquiries brought out the following facts:

1. The need of storage on the distribution system, with resulting flattening of peak loads.

2. An unusual amount of trouble from algae and microscopic organisms in a number of surface supplies.
3. An unusual drop in water level in ground water supplies in some cases, in others none, although some of the later experienced fear that trouble might still be encountered.
4. None of the deep wells supplies seem to have shown any effect as yet. This refers to larger plants only.
5. Practically all plants showed greater total pumpage than for previous corresponding periods.
6. Many plants showed higher maximum hourly rates compared to average day, although some, notably Indianapolis, showed a higher ratio in 1925, than in 1930.
7. A number reported the effect of the general depression on demands, mainly on total pumpage.
8. Advantage of increased per cent of metering.

One unusual effect of the drought was reported by Amiss at Shreveport, where a 24-inch force main failed due entirely to the shrinkage of the ground as a result of the drought.

So far as the design of pumping stations and purification plants is concerned, it would seem that there has not been established any very logical reason for changing the basic assumptions that have followed the best engineering design. If the water consumption demands are ascertained accurately to meet the conditions of the city in question, and the usual factors of safety used in determining the size of pumping stations and purification plants, this factor of safety, particularly if ample storage on the distribution system is afforded, should be able to take care of situations similar to last year's drought. As a matter of fact, in a great many places tests equally as severe as last year have already been experienced.

In the design of water supply itself, as distinct from the pumping and purification works, present methods would necessarily include a study of the rainfall records during the drought. Here again it would seem that this fact would make unnecessary any radical changes at least in the manner of ascertaining the required storage in each case. Proper design in such matters has always carried a large factor of safety.

I think the economic feature mentioned by Mr. Berry in his paper is quite pertinent. Assuming that a plant having adequate design based on present practice, would not be able to meet the most severe conditions without a slight curtailment of service. there is a question

from the standpoint of engineering economics as to whether or not an attempt should be made to meet conditions occurring at what can be reasonably termed, long cycles. The drought has at least brought out quite clearly the need of proper engineering design and it has brought that point out much more clearly than it has the need of changing any of our present basic assumptions.

The above statements should not be interpreted as in any way belittling the effect of the 1930 drought, nor to ignore the fact that many plants were seriously affected, but merely as a statement of a belief that more facts are necessary before changes in the definitely basic assumptions should be made.

Ezra B. Whitman:[5] The drought of the past year has caused many serious problems in water supply to cities throughout the country. Many cities have been compelled to curtail the use of the water because of lack of supply. The hot dry weather, with almost continuous sunshine has been ideal for the development of algae growths in water supplies, and with such growths came the attendant tastes and odors. Other cities, taking their sources of supply from polluted streams, find the pollution increased to a considerable extent due to the fact that the polluting matter remained constant while the diluting supply of fresh water diminished to a very large degree. Other cities have had more or less serious shortage of water due, not to an insufficient source of supply, but to the fact that the pumping station, filter equipment and possibly the distributing mains, have been of insufficient size to meet the extraordinary draught due to the extremely hot and dry weather. The discussion that follows will be limited very largely to the question of quantity of water available at the source of supply.

Our firm has had occasion, during the past year, to study the effect of the 1930 drought on a number of water supplies. During the past few years we have been engaged in the design and construction of a new supply for the City of Albany. This supply provides for a storage reservoir on Hannacrois Creek with a capacity of 12 billion gallons. Hannacrois Creek itself has a water shed area above the dam of 32 square miles. Basic Creek flowing in an adjacent water shed, is diverted into this reservoir. On Basic Creek, a diversion dam has been constructed and a tunnel, and the capacity of this dam

[5] Consulting Engineer, Baltimore, Md.

and tunnel is such that practically all of the water flowing in Basic Creek, except that from the most excessive storms, will be diverted into the Alcove Reservoir. The area of the Basic Creek water shed above the point of diversion is 16 square miles, giving a total area tributary to the Alcove Reservoir of 48 square miles.

In our preliminary figures as to the available flow from this area, it was estimated that it would safely supply the City of Albany with 30 million gallons of water per day. The gates draining the reservoir were closed on January 1, 1929 and by July of last year, 7,300,000,000 gallons of water had been stored behind the dam. During September and October, 51 million gallons of water were released from the reservoir for the use of the city of Ravena, which city takes its supply from Hannacrois Creek several miles below the dam. During August September and October, the evaporation from the water surface of the lake was greater than the inflow of the stream by approximately 250 million gallons, and by February, 1931, the amount of water stored in the reservoir was still 7,300,000,000.

It was not surprising that the evaporation during the peak of the drought was greater than the stream flow, as the stream during such times almost dries up, the flow being a mere trickle from pool to pool. During the dry spell of the latter part of 1929, the stream flow was so low in Hannacrois Creek that many fishes died in the stream and a number of pools were practically dry. Many of the local people knowing of this condition, thought that Albany was extremely foolish to attempt to secure its water supply from a stream which practically went dry in the summertime.

The water which was stored in the Alcove reservoir was not used by the City, as the City has continued through the present time, to take its supply from the Hudson River. In the meantime, a 20 mile pipe line connecting the reservoir with the city has been constructed and also a filtration plant and distribution reservoir north of the City. The whole system is now nearing completion and we expect to put it into operation about the middle of this year. During this time, the spring rains have filled the reservoir, and many hundreds of millions of gallons have flowed over the spillway.

During April of this year, we made calculations to determine what would have been the results had Albany been taking its water supply from the new source. We had the records of the stream flow of both Basic Creek and Hannacrois Creek over a period of years and these records showed that on May 1, 1930, the reservoir would have

been filled. From that time on, with a draught of 30 million gallons on the reservoir, the reservoir would have been drawn down until March 1, 1931, when there would have been 5 billion gallons left in storage. The spring rains during March and April of this year, would have restored the available supply behind the dam to 10 billion gallons. Assuming that the year 1931 to 1932 would be the same as the past year, we then calculated what the storage would be this year and find that by February, 1932, with the same stream flow as existed during the drought period of 1930, the available storage in the reservoir would still have been 3 billion gallons.

Further assuming that the year 1932 to 1933 would again repeat the low stream flow of last year, we find that the available storage in February, 1933 would be one billion gallons. The City of Albany is using at the present time, approximately 20 million gallons a day and with a reservoir in operation, there would have been no question of water shortage even should there have been for three years in succession, droughts as severe as occurred last year. Had the City been using the 30 million gallons a day, with a three year drought period as severe as last year, there would still have been left in the reservoir one billion gallons of available storage. These calculations indicate that the basis on which the new supply for Albany has been designed has been a conservative one and we feel no doubt that the City will be able to obtain 30 million gallons a day from the new Hannacrois-Basic supply, even under the most severe conditions that could possibly occur, namely a three year continuous drought as severe as that of last year.

Another city which just barely escaped through the drought period is Lynchburg, Virginia. This City takes its water supply from Pedlar River and Mr. James H. Fuertes designed the dam and supply works for Lynchburg about 1906. He built a dam holding 347 million gallons at a point on the River where the area of the water shed above the dam is 33.21 square miles. In 1927 the crest of the dam was raised $2\frac{1}{2}$ feet, increasing the available storage to 404 million gallons. In 1930 the reservoir was drawn down by the end of October, so that but a few days supply remained when rains in early November saved the situation.

Another very helpful condition in Lynchburg was due to the installation of meters throughout the City over a ten-year period, from 1920 to 1930. In 1920 the average daily consumption was 6 million gallons a day, while in 1930 it was only 4 million gallons a day, and

this without any restrictions on the use of water. In 1929 the daily consumption was 3.85 million gallons a day. The problem in Lynchburg was to secure greater storage and the question was whether it would be cheaper to raise the existing dam or build a new dam higher up on the water shed. It was found that by raising the existing dam 10 feet, the volume of storage would be increased 50 per cent and based on the 1930 run-off figures, this would satisfy the requirements of the City until about the year 1947. This work would be very much cheaper than building an entirely new dam and the city decided to go ahead on this project and the work is now well under way.

Frederick, Maryland, secures its water supply from the mountains north of the City, taking water from two small streams, Fishing Creek and Tuscarora Creek. On Tuscarora Creek, the City has built a small diversion dam holding practically no storage and the area behind this dam is approximately $3\frac{1}{2}$ square miles. On Fishing Creek, the City built a dam with a storage capacity of 50 million gallons on a water shed of approximately 7 square miles. These streams flow in the Monocacy River and the gauging stations on this river showed a yield from the entire area of over 400 square miles of considerably less than 100,000 gallons per square mile per day. On the 29th of August, 1930, the yield from Tuscarora was 91,200 gallons, and from Fishing Creek it was 154,000 gallons per square mile, while from the Monocacy area above the gauging station, the yield was 49,000 gallons per square mile. Due to this high yield from the areas from which the City obtained its water supply, the City was able to get through the past year by stopping all sprinkling of lawns and the use of water for flushing streets and washing automobiles.

Several hundred thousand gallons additional water were obtained from springs near the City, which was pumped into the water supply. The problem in Frederick of obtaining more water during the dry summer months, was quite complicated, due to the fact that the mountain streams were on such steep slope that it was impossible to provide storage within a reasonable distance of the City. The Monocacy River water is hard and turbid and contains contamination from quite a few towns and communities and is therefore an undesirable source of supply.

The Linganore Creek, one of the main tributaries of the Monocacy, with an area of water shed of approximately 80 square miles, provided a much better quality of water than the Monocacy, and the City has proceeded with plans to install a pumping station and filter plant on

Linganore Creek in order to secure additional supply. The mountain sources will provide sufficient quantity of water throughout the greater part of the year and this new supply will be called upon only during drought periods.

In Baltimore about 1911, the writer as Chief Engineer of the Water Department, built the Loch Raven dam to elevation 192, and made studies of the yield from the Gunpowder River with the Loch Raven dam raised to crest elevation of 240 A.M.T., and storing at that elevation, 23 billion gallons of water. The dam was finally raised to this elevation about 1920 and the stream flow records showed that it would furnish the City a safe supply of 145 million gallons a day.

During the year 1930, the average water consumption for Baltimore was 113 million gallons per day and the Loch Raven reservoir was drawn down at its lowest point in December to such an elevation that there was 14 billion gallons of water stored behind the dam. Had the water consumption of Baltimore been at the rate of 145 million gallons during the year, instead of 113 million gallons, there would have been left in the reservoir only 2 instead of 14 billion gallons. Since December, the rains have nearly filled the reservoir until at the present time, it holds 20½ billion gallons, or an increase of 6½ billion gallons since December.

This shows that Loch Raven would have been capable of furnishing the estimated draught of 145 million throughout the drought year of 1930. If we have a continued drought this year, however, the draught of 145 million might produce a water shortage. With a water consumption remaining practically where it was last year and the stream flow, due to drought conditions, continuing as low as it was throughout last year, the Loch Raven dam will provide Baltimore with a safe supply and have approximately 10 billion gallons left in it at the end of this year. It would appear therefore that the Baltimore water supply is safely and adequately provided for, even though there is a continuation of the drought this year as severe as occurred last year.

There was a shortage of water in certain sections of Baltimore, due, not to any lack of water in the reservoir, but rather to lack of capacity in certain pumping stations. When the writer was Chief Engineer of the Water Department, the highest section of the City, largely in a suburban area, was supplied from a pumping station by two 5 million gallon pumps, pumping water into a standpipe of about 300,000

gallons capacity. During the hot dry days of the summer, with practically every householder sprinkling his lawn, this standpipe would be emptied in spite of the fact that both pumps would be operated to their full capacity. This same condition existed in Baltimore in certain areas during the past year, although the original condition which occurred during the writer's term as Chief Engineer, was corrected by putting in two 12½ million gallon pumps in place of the 5 million gallon pumps.

There is no doubt but that hot dry weather in suburban areas places a great demand on a water system, and as is very well brought out in Mr. Berry's paper, the question is whether a system should be designed to meet extraordinary conditions that occur only at long periods or whether it is better occasionally to put restrictions on the water users and stop the sprinkling of lawns. When this was done in Frederick, however, we know that there were a number of citizens who came to the municipal authorities saying that they would much rather pay more for the water and get all they wanted, as the inability to water lawns and shrubbery caused a loss of hundreds of dollars because the vegetation died through lack of sufficient water.

It is interesting to note that, while the average use of water in Baltimore during 1930 was 113 million gallons per day, the maximum use of water during the year was at the rate of 170 million gallons per day for two hours, while the maximum consumption on any single day was 145 million gallons per day, and the average daily use for the maximum month was 125,700,000. Were it not for the fact that Baltimore City is well provided with storage reservoirs, it will be readily seen that the demand on the filtration and pumping equipment would require a very large increase in capacity over what can be maintained with the storage the City has available.

George G. Earl:[6] We are very fortunate in New Orleans in having enough water supply, always. The effect of the drought there was in the fact that we had a low river for a very much longer time than normal, and had a slight increase of salt in the water, up to as high as 150 p.p.m. maximum, for a period of several days. That is the worst and the only effect that was noticeable.

The interesting thing is that if you went ten miles further down the river you would find that they had twice that much salt, and

[6] Consulting Engineer, New Orleans, La.

another ten miles down they would have three or four times that much, showing that the New Orleans intake is pretty nearly on the line of satisfactory conditions for the extremely low flow of the drought years in the Mississippi River.

What has been most interesting in New Orleans is not the shortage, but the reverse, in the rainfall conditions where we had seven rainfalls n a five-year period that exceeded by 45 per cent in intensity the seven greatest rainfalls of the prior thirty-one year period. I do not think that that is of special interest to the water supply people, but the immediate removal of these frequent and very intense rainfalls by pumping where the whole runoff from an area of 29,000 acres has to be pumped through a lift of 12 feet or more, and half of it pumped through an intermediate lift, before it is finally disposed of, is a serious problem, and has led New Orleans to double its power and pumping capacity for the more rapid removal of such intense rainfalls.

Samuel B. Morris:[7] California has been experiencing a very dry year this year. In fact, most of California has been in a dry cycle of years, beginning with the year 1917. In southern California there have only been three years in the last fifteen when we have had as much as normal rainfall. One year of those three was of excessive rainfall. Take a year with slightly more than normal rainfall, following years of drought preceding it, and we do not get as much as a normal runoff. So that in the last fifteen years in Southern California we have only had one year that produced large runoff and two others with slightly more than normal runoff. We are getting quite used to periods of drought in California.

There is a great deal of interest, not only on the part of engineers and those people empowered with decisions in these matters, but in the public at large. In California they are awake to the water problem. It might interest you to know that the Governor of California has called a special session of the Legislature this summer to consider the State wide water plan in California, which is largely one of irrigation and not of domestic water use. It is very interesting to hear the discussions. We have in every case to consider the dry periods which we can predict, and I might say that the one we are passing through in Southern California is not nearly so dry, or so sub-normal, as the period from 1893 to 1904.

[7] Chief Engineer, Water Department, Pasadena, Calif.

In Northern California the period we are passing through is drier than that earlier record. Then we have records that go back to those that were taken by the Mission Fathers in California, who recorded the amount of grain grown from certain amounts of seed, and we find that there were very critical dry cycles in the periods before we had any complete records of actual rainfall. It is a very great problem and we are very greatly interested in efforts to determine any means of predicting these dry cycles.

THE DROUGHT OF 1930

By John C. Hoyt[1]

Although the drought of 1930 may be considered the severest occurrence of its kind yet on record, in many respects it outranks several past dry spells only by a small margin. Thus it is important not as an isolated freak of the weather, but as a menace which is virtually certain to recur. Future planning for the many uses of water must be based on a thorough realization of this fact. If supplies are to be adequate, full provision must be made for such a recurrence at any time, and this allowance must be based upon a complete statistical knowledge of what has happened. The drought of 1930 may serve for some years to come as a low point in the curve of probability upon which future estimates will depend. It is essential that the curve be anchored to a point whose accuracy is beyond question.

This report is offered as an approach to a solution of this problem. The report seeks to outline the nature and extent of the drought of 1930 as compared with past droughts, in terms of rainfall, run-off, and ground water. It sketches the effects upon water supplies for a variety of human purposes, including agriculture, power, nagivation, city supply and waste disposal, and recreational and industrial uses; it also touches upon the social, political, and economic elements involved.

The basis for the report consists of data collected in the various States under the direction of 32 district engineers of the United States Geological Survey, supplemented by data made available through the United States Weather Bureau, Bureau of Agricultural Economics, Public Health Service, Office of the Chief of Engineers, American Red Cross, and various State agencies. Acknowledgment for assistance and suggestions in the preparation of the report is hereby given to the district engineers and also to Oscar E. Meinzer, B. J. Peterson, Guy C. Stevens, and Lloyd L. Harold, of the United States Geological Survey; to Alfred J. Henry and Joseph B. Kincer, of the United States Weather Bureau; and to John C. Cramer, Jr., of the American Red Cross.

[1] Hydraulic Engineer, United States Geological Survey, Washington, D. C.

In many sections of the country drought conditions continued into 1931. The distribution of precipitation during the growing season of 1931, however, in practically all sections was favorable to plant growth, and so far as vegetation is concerned the drought ended with the growing season of 1930. As related to water supply, the effects of the drought were still being felt in the fall of 1931. A complete report on the drought of 1930 cannot be presented until additional data are available and conditions have become more normal. At that time such a report will be issued by the United States Geological Survey.

ABSTRACT

Precipitation and run-off records indicate that droughts of major proportions, both in severity and in extent, have occurred at intervals of 15 to 20 years and that droughts of equal severity but of less extent have occurred at intervals of 3 to 6 years. The drought of 1930 was a major drought, in which some of the outstanding features were as follows:

1. The year 1930 began with water conditions in most States about normal.

2. The area affected and the deficiency of annual precipitation over this area were slightly greater than in any previously recorded major drought. Neither of these conditions, however, was materially worse than for the major droughts of 1894 and 1910.

3. In most of the areas affected the duration of the drought was much longer than that of any previous one.

4. The minimum annual precipitation records were broken in 18 States, and the monthly precipitation in many localities was below normal for 8 to 14 consecutive months.

5. In many of the areas affected the annual stream flow during the water year ending September 30, 1930, did not fall below previously established minima, and but few records of minimum daily flow were broken. On the other hand, for many streams the monthly flow and the annual flow on the basis of the calendar year reached new minima and for most streams all records of long-continued low flows were broken.

6. Ground-water levels were rapidly reduced to a point below which they did not fall appreciably and the later fall was very slow, indicating that the available ground-water supply for most river drainage basins is so great that it is adequate to maintain the stream

flow at practically a fixed minimum without appreciable change for a considerable period of time and probably through any drought that may be expected.

7. Normal activities, both economic and social, were probably interfered with to a greater extent than during any previous drought, and the resulting losses were greater. The effects of previous droughts related primarily to economic and social activities The effects of the drought of 1930 were also an important factor in political activities.

The drought emphasized the following needs:

1. The collection in more detail of the hydrologic data required in wise planning and use of our water resources. This should include a country-wide research into the quality and quantity of both surface and ground water supplies, and also the collection of information leading to the best methods of conservation of supplies for their highest ultimate use.

2. More adequate works for storage of both surface and ground water supplies.

3. More care in planning, so that development will be kept within the limits of available water supplies.

4. More adequate facilities for the disposal of sewage and industrial wastes, in the interests of health and social betterment.

5. More systematic planning and operation of agriculture, to the end that all farms shall produce food crops as well as money crops, in order that adequate food supplies will be insured during years when returns for money crops are small.

In the studies leading to this report the following observations were made:

1. That a knowledge of the occurrence of ground water is essential in surface-water studies.

2. That the effects of vegetation are important factors in the consideration of water supplies during the growing period.

3. That precipitation data must be used with great caution in water-supply studies and that there is practically no relation between precipitation and low-water flows.

4. That conclusions drawn from precipitation or stream-flow data expressed as percentages of the mean may lead to erroneous conclusions.

5. That conditions in different drainage basins are so varying that estimates of low flow, based on comparison with adjacent areas or on precipitation data, can not be made with any degree of certainty.

GENERAL FEATURES

When the precipitation in an area that is ordinarily classed as humid is insufficient to sustain typical vegetable growth adequately, or to furnish water enough to meet the needs of established activity, drought conditions may be said to prevail.

During 1930 precipitation was below the mean in 40 States, and in 19 of these previously recorded minima were broken. This deficiency in precipitation, accompanied by excessive heat and other unfavorable conditions, resulted in a widespread drought, which differed in severity in different localities.

Unfavorable crop reports early in the summer first called attention to the approaching seriousness of the drought. These were followed by reports from many localities on the shortage of water supplies for domestic and other uses. By the middle of the summer the effects of the drought, which were intensified by the abnormal heat, were receiving general attention by the press of the country, and the situation was referred to as "the great drought of 1930." At the end of the summer it became evident that in many localities relief measures would be necessary, and steps were taken, by both private and governmental agencies, to meet needs as they arose. Differences of opinion as to methods of providing the relief created marked political issues and resulted in much emotional publicity, in which great emphasis was given to conditions in certain localities where the effects of the drought were most severe. All this tended to magnify the unfavorable aspects of the situation.

The United States Weather Bureau in 1908[2] reported that "The greatest drought this country has experienced in the last 100 years, both as to intensity and extent of territory covered, culminated in the middle Mississippi and Missouri Valleys in 1894 and in the Lake region and Atlantic coast districts in 1895." It also reported that there was a serious drought in 1881 and stated that "It affected practically the whole of the country east of the Mississippi and lasted from July to September. . . . . The most striking characteristic of this drought was its duration and attendant high temperatures. Vegetation and staple crops were seriously damaged, and in the latter stages of the drought there was a scarcity of water for domestic use and for manufacturing purposes. In many places scores of shops and factories were obliged to shut down for lack of water." Later

[2] Bulletin Q, United States Weather Bureau, Climatology of the United States, 1906, by Alfred J. Henry, page 51.

Weather Bureau reports indicate that there were marked drought conditions during 1910.

In reporting the drought of 1894–95 it was stated that "Since the drought of these two years will probably become historic, a record of the departure of the annual precipitation from the normal is here given for future reference and comparison." This record is shown in table 1, which has been expanded to include 1910 and 1930 and the percentage of the area of the 36 non-arid States in which precipitation was deficient.

TABLE 1

*Departures from normal precipitation in drought years 1894, 1895, 1910, and 1930, in inches**

DISTRICT	1894	1895	1910	1930
New England	−8.1	−5.3	−6.7	−7.6
Middle Atlantic States	−5.3	−9.1	−5.5	−12.8
South Atlantic States	−4.2	−3.7	−9.0	−9.3
East Gulf States	−9.0	−8.6	−7.6	−4.8
West Gulf States	−6.8	−6.7	−7.8	−2 9
Ohio Valley and Tennessee	−11.0	−11.0	−1.2	−13.4
Lower Lake region	−4.5	−5.8	−5.9	−6.5
Upper Lake region	−2.0	−7.1	−6.5	−9.3
North Dakota	−0.5	−1.1	−8.0	−3.5
Upper Mississippi Valley	−12.0	−7.8	−9.8	−6.8
Missouri Valley	−8.8	−2.9	−5.0	−4.5
Northern slope	−1.4	−0.4	−3.0	−0.9
Middle slope	+0.4	−1.6	−7.7	−0.4
Southern slope	−3.7	+7.2	−12.2	−0.9
Southern plateau	−3.9	+0.4	−3.5	−1.0
Middle plateau	+0.2	−2.6	−3.7	+0.3
Northern plateau	+0.9	−4.5	−1.5	−1.9
North Pacific	+11.7	−4.1	−2.3	−12.6
Middle Pacific	+1.8	−5.6	−10.9	−7.5
South Pacific	−4.6	−4.4	−7.1	−1.0
Percentage of area of non-arid States in which precipitation was deficient	54.3	44.5	50.4	55.9

* Normal precipitation determined from data available at the dates indicated.

The records indicate, therefore, that during the last 50 years five

major droughts have occurred, which have not differed greatly in area covered or in the magnitude of deficiency from normal annual precipitation. The center of area of these droughts, however, was not the same. The drought of 1930 was, in general, of longer duration than the other four. The information available indicates that in 1930 normal activities were probably interfered with to a greater extent than during any previous drought and that the resulting losses were greater. It is probable, therefore, that while the drought of 1930 is not to be belittled, it may not have been as exceptional as the publicity at the time indicated, and it probably would not have received as much attention if it had not occurred simultaneously with general financial and industrial depressions, which reduced the ability of those in the drought areas to meet the situation adequately without outside relief. Such relief was provided by gifts through the Red Cross and loans by the Federal Government.

For the purposes of this report the States have been divided into two groups—first, those which have large arid areas, including Texas and the 11 States lying wholly west of the 100th meridian; second, those which have no arid areas comprising the 36 States east of and including North Dakota, South Dakota, Nebraska, Kansas Oklahoma, and Louisiana.

Agriculture and many other activities are conducted so differently in the arid and non-arid States that the consideration of droughts in the two groups can not be made on a comparable basis. The precipitation, stream flow, and other data used in this report relate to both the arid and the nonarid States. The discussions based on these data, however, apply only to the non-arid States, unless otherwise stated. The comparative studies have, in the main, been limited to the years for which the United States Weather Bureau has published records of annual precipitation by States.

Records of precipitation and stream flow give an index for studying droughts and generally will serve to answer questions relative to the area covered, the severity, the frequency, and the duration. Additional facts, however, are needed in considering the nature and extent of resulting damages and losses.

EXTENT, SEVERITY, FREQUENCY, DURATION

The map in figure 1 gives a general picture of the drought conditions during 1930. On this map is indicated, by States,[3] the pre-

[3] This report follows the Weather Bureau publications in treating the New States as a unit and Delaware and Maryland as a unit.

cipitation during 1930, expressed as percentage of the mean for the period of record, and also the year having the lowest precipitation. In 6 of the 12 arid States the precipitation was below the mean, and in one of these, Oregon, it was the lowest on record. In 34 of the 36 non-arid States the precipitation was below the mean, and in 18 of these it was the lowest on record; these 18 States were in the North Atlantic, Ohio River, and Great Lakes drainage basins and included all States east of the Mississippi River and north of the southern boundary of Tennessee and Virginia except Illinois and Wisconsin. The deficiency in precipitation in these 18 States was greatest in

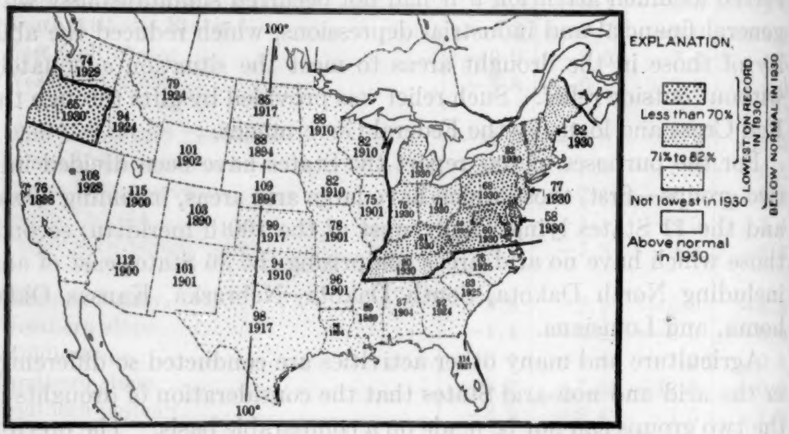

Fig. 1. Average Precipitation in 1930, in Percentage of Mean for Period of Record (Upper Figures) and Year of Lowest Precipitation (Lower Figures)

In the area indicated by heavy outline the precipitation in 1930 was the lowest of record.

Delaware, Maryland, West Virginia, Virginia, and Kentucky, and ranged from 58 to 61 per cent of the mean. In 9 other of the 36 non-arid States the precipitation did not exceed 80 per cent of mean.

The figures of annual and monthly precipitation for each State, which for most States do not begin prior to 1885, as shown by the bar graph in figure 2 for Virginia, one of the States most severely affected by the drought, afford a ready means for studying variations in precipitation. A study of these graphs shows that the six years of lowest precipitation for each State include not only all years having large deficiencies in precipitation, but for some States they include

also a few years of more moderate deficiencies. These years have, therefore, been considered as having major deficiencies in precipitation—in this discussion called simply "deficient precipitation." The deficiency in precipitation for the great majority of these years is 20 percent or more below the mean. These deficient years, with

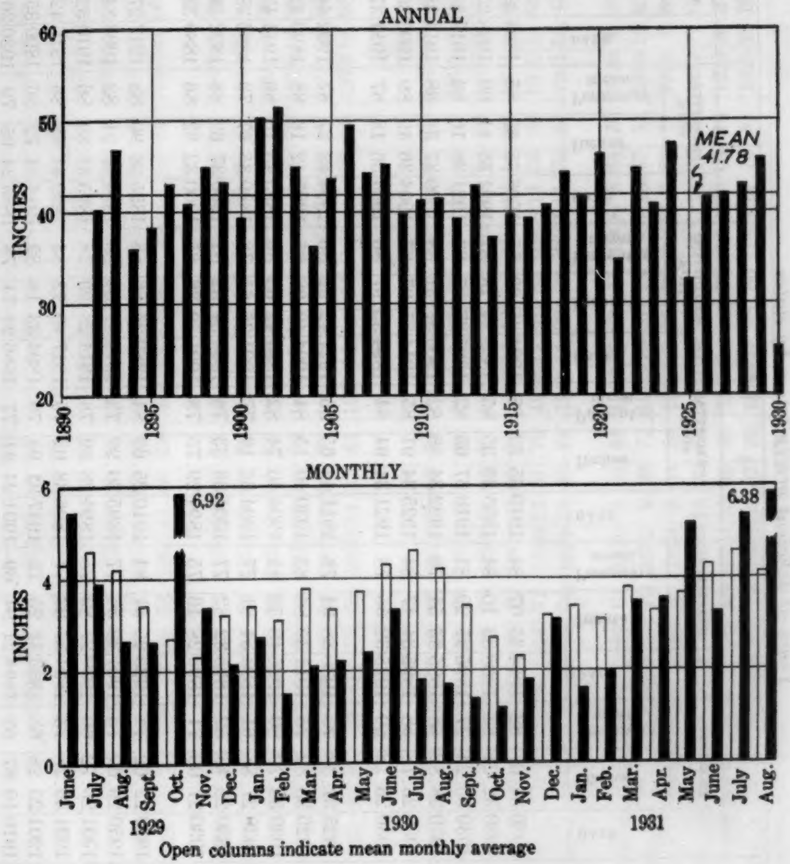

FIG. 2. ANNUAL PRECIPITATION IN VIRGINIA, 1892–1930, AND MONTHLY PRECIPITATION, JUNE, 1929, TO AUGUST, 1931

the corresponding precipitation expressed in inches and in percentage of the mean, are listed in table 2, arranged by States in the order of magnitude of deficiency, from lowest to highest. This table shows that the major deficiencies in precipitation were not simultaneous in all the States. For example, in the non-arid States there were

TABLE 2

Years of deficient precipitation by states

STATE	1			2			3			4			5			6			MEAN PRECIPITATION FOR PERIOD OF RECORD
	DATE	PRECIPITATION		DATE	PRECIPITATION		DATE	PRECIPITATION		DATE	PRECIPITATION		DATE	PRECIPITATION		DATE	PRECIPITATION		
		Inches	Percent of mean		Inches	Percent of mean		Inches	Percent of mean		Inches	Percent of mean		Inches	Percent of mean		Inches	Percent of mean	
Non-arid																			
New England	1930	34.07	82	1914	35.07	84	1910	35.52	85	1924	35.62	85	1908	35.62	85	1894	35.85	86	41.70
New York	1930	32.21	82	1908	33.10	84	1895	33.35	85	1899	34.18	87	1921	35.41	90	1923	35.46	91	39.18
New Jersey	1930	35.24	77	1895	37.29	81	1918	37.65	82	1885	37.87	83	1921	38.16	83	1916	38.17	83	45.77
Pennsylvania	1930	28.82	68	1895	33.51	79	1922	34.88	82	1900	37.31	88	1909	37.38	88	1914	38.24	90	42.39
Maryland and Delaware	1930	23.78	58	1895	34.47	84	1925	34.91	85	1914	35.97	87	1904	36.49	89	1900	36.66	89	41.16
Virginia	1930	25.16	60	1925	32.55	78	1921	34.94	84	1894	35.97	86	1904	36.18	87	1914	37.17	89	41.78
North Carolina	1925	37.33	75	1930	38.04	76	1911	42.65	86	1921	42.92	86	1904	43.27	87	1902	44.46	89	49.82
South Carolina	1925	35.82	75	1911	39.80	83	1930	40.15	84	1904	40.98	85	1927	42.16	88	1890	42.29	88	48.10
Tennessee	1930	39.79	80	1925	40.50	81	1904	40.74	82	1894	42.65	86	1895	43.10	86	1914	43.97	88	49.84
Kentucky	1930	27.88	61	1894	34.81	77	1904	35.10	77	1901	35.65	78	1889	35.97	79	1895	38.47	85	45.47
West Virginia	1930	25.43	59	1895	32.82	77	1904	33.33	78	1894	34.52	81	1900	37.62	88	1892	38.33	90	42.74
Ohio	1930	27.00	71	1895	28.46	75	1894	29.75	78	1901	32.36	85	1900	32.82	86	1889	33.41	88	38.01
Michigan	1930	22.62	74	1925	25.51	84	1910	25.69	84	1889	26.86	88	1895	26.90	88	1917	27.21	89	30.53
Indiana	1930	29.69	75	1901	30.56	77	1895	30.99	78	1914	31.54	80	1894	32.21	82	1908	34.30	87	39.53
Illinois	1901	25.72	69	1930	27.89	75	1894	28.89	78	1914	28.99	78	1895	31.89	86	1910	32.09	86	37.18
Arkansas	1901	35.28	73	1924	37.03	77	1896	38.02	79	1917	40.72	84	1899	41.49	86	1916	42.18	87	48.31
Missouri	1901	25.28	63	1930	31.25	78	1917	31.94	79	1894	33.18	82	1914	34.72	86	1890	35.71	89	40.27
Iowa	1910	19.87	63	1894	21.94	69	1901	24.41	77	1886	24.71	78	1889	24.95	79	1930	26.10	82	31.72

Wisconsin	1910	21.41	70	1902	22.91	75	1895	23.14	76	1930	25.08	82	1891	26.14	86	1901	26.15	86	30.45
Minnesota	1910	14.73	57	1889	19.08	74	1923	19.81	77	1929	20.56	80	1917	20.99	82	1894	21.63	84	25.66
Florida	1927	40.71	77	1917	41.36	78	1921	45.24	86	1895	45.50	86	1916	47.10	89	1911	47.40	90	52.87
Georgia	1904	37.17	74	1893	40.29	81	1927	40.65	81	1921	40.94	82	1925	41.00	82	1916	43.50	87	50.08
Alabama	1904	39.21	74	1889	43.30	82	1914	44.90	85	1925	45.20	85	1910	45.20	85	1896	45.25	86	52.93
Mississippi	1889	38.31	72	1924	40.06	76	1904	41.48	78	1896	43.13	81	1899	44.52	84	1917	45.16	85	53.06
Louisiana	1924	38.47	69	1917	40.22	72	1899	42.29	76	1904	44.18	79	1902	46.32	83	1896	46.36	83	55.72
Oklahoma	1910	19.24	59	1917	22.39	69	1901	22.70	70	1896	23.78	73	1893	25.49	78	1894	25.57	78	32.65
Kansas	1917	19.60	72	1910	19.67	72	1893	20.25	75	1894	20.72	76	1890	21.16	78	1901	21.35	79	27.14
Nebraska	1894	13.30	57	1893	16.80	71	1910	17.18	73	1890	17.18	73	1895	18.70	79	1916	19.08	81	23.53
South Dakota	1894	15.30	74	1910	15.49	75	1925	15.90	77	1895	16.05	78	1890	16.43	80	1898	16.50	80	20.60
North Dakota	1917	10.92	62	1910	12.19	69	1929	14.32	81	1907	14.41	82	1913	14.69	84	1930	14.90	85	17.59
Arid:																			
Texas	1917	16.21	53	1893	20.47	67	1910	21.46	71	1901	22.23	73	1909	23.45	77	1924	23.50	77	30.37
New Mexico	1910	9.46	65	1917	9.49	66	1892	9.51	66	1902	9.97	69	1894	10.47	72	1924	10.65	74	14.45
Colorado	1890	11.97	71	1888	12.00	72	1893	12.86	77	1889	13.73	82	1924	13.75	82	1903	13.80	82	16.77
Wyoming	1902	9.81	67	1919	10.46	72	1900	10.95	75	1910	12.12	83	1901	12.14	83	1921	12.58	86	14.60
Montana	1904	11.04	71	1919	11.14	71	1930	12.37	79	1895	12.97	83	1928	13.06	84	1929	13.08	84	15.61
Idaho	1924	12.46	71	1929	13.06	75	1928	13.60	78	1898	14.22	82	1904	14.70	84	1901	15.40	88	17.42
Nevada	1928	4.87	54	1924	5.49	61	1910	5.53	61	1929	5.83	65	1908	6.34	70	1926	6.39	71	9.02
Utah	1900	8.38	64	1902	9.17	70	1892	9.50	72	1903	10.21	78	1924	10.57	81	1898	10.61	81	13.10
Arizona	1900	8.30	61	1899	8.41	62	1924	8.68	64	1910	8.99	66	1928	9.67	71	1904	9.84	73	13.53
California	1898	10.35	43	1923	14.13	59	1929	15.00	62	1917	16.48	68	1910	16.77	70	1924	17.05	71	24.08
Oregon	1930	22.73	65	1929	22.79	65	1924	23.68	68	1918	24.59	70	1925	26.04	74	1928	26.27	75	35.00
Washington	1929	23.67	70	1922	24.67	73	1911	25.97	76	1930	27.28	80	1924	27.70	81	1925	28.09	83	34.00

TABLE 3

Years of deficient precipitation by states

Numbers indicate order of deficiency

NON-ARID STATES

YEAR	New England	New York	New Jersey	Pennsylvania	Maryland and Delaware	Virginia	North Carolina	South Carolina	Tennessee	Kentucky	West Virginia	Ohio	Michigan	Indiana	Illinois	Arkansas	Missouri	Iowa	Wisconsin	Minnesota	Florida	Georgia	Alabama	Mississippi	Louisiana	Oklahoma	Kansas	Nebraska	South Dakota	North Dakota
Record starts	1888	1890	1885	1888	1895	1892	1887	1887	1884	1889	1891	1883	1888	1887	1878	1891	1888	1873	1891	1886	1892	1892	1884	1888	1891	1893	1887	1876	1890	1892
1885			4																											
1886																		4												
1887																														
1888																														
1889										5		6	4					5		2			2	1						
1890								6									6										5	4	5	
1891																			5											
1892											6																			
1893																						2				5	3	2		
1894	6					4			4	2	4	3		5	3		4	2		6						6	4	1	1	
1895		3	2	2	2				5	6	2	2	5	3	5				3		4							5	4	
1896																3							6	4	6	4				
1897																														
1898																													6	
1899		4														5								5	3					
1900				4	6						5	5																		

ARID STATES; SUMMARY, U. S.; SUMMARY, NON-ARID STATES

YEAR	Texas	New Mexico	Colorado	Wyoming	Montana	Idaho	Nevada	Utah	Arizona	California	Oregon	Washington	YEAR	U. S.: First order	Second order	Third order	Fourth order	Fifth order	Sixth order	Total	Non-arid: First order	Second order	Third order	Fourth order	Fifth order	Sixth order	Total: States	Total: Percent of total area	Percent of mean precipitation for area
Record starts	1891	1892	1888	1899	1895	1898	1890	1892	1897	1897	1890	1890																	
1885													1885				1			1				1			1	0.5	82.7
1886													1886				1			1				1			1	3.6	77.9
1887													1887															....	....
1888			2										1888		1					1								....	....
1889			4										1889	1	2		2	2	1	8	1	2		1	2	1	7	24.6	80.0
1890			1										1890	1			1	2	2	6				1	2	2	5	21.9	83.2
1891													1891					1		1				1	1		1	3.6	85.8
1892		3						3					1892			2			1	3						1	1	1.6	89.7
1893	2		3										1893		3	2		1		6		2	1		1		4	16.7	77.1
1894		5											1894	2	2	2	5	2	8	21	2	2	2	5	1	8	20	54.3	79.3
1895					4								1895		6	3	3	4	1	17		6	3	2	4	1	16	44.5	81.9
1896													1896			1	2		2	5			1	2		2	5	15.6	81.0
1897													1897															....	....
1898						4		5		1			1898	1			1	1	1	4						1	1	5.0	80.1
1899									2				1899		1	1	1	2		5			1	1	2		4	12.8	82.8
1900				3				1	1				1900	2		1	1	2	2	8				1	2	2	5	8.1	87.9

1901	..	..	..	..	..	..	..	..	..	4	..	4	..	2	1	1	1	3	6	..	..	..	..	..	..	3	6	..	..	..	4	..	..	5	..	6	..	..	..	..	..	..	1901	3	1	2	3	1	3	13	3	1	2	2	..	2	10	34.4	75.4
1902	..	..	..	..	..	..	6	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..	..	..	5	..	..	..	..	..	..	4	..	1	..	..	..	2	..	..	..	..	1902	1	2	..	1	1	1	6	..	1	..	..	1	1	3	10.2	83.6
1903	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6	..	..	..	..	4	..	..	..	..	1903	..	..	..	1	..	1	2	..	..	..	..	..	..	..	....	....
1904	..	..	..	..	5	5	5	4	3	3	3	..	..	..	..	..	..	..	..	..	..	1	1	3	4	..	..	..	..	..	..	..	..	..	1	5	..	..	6	..	..	..	1904	3	..	4	2	5	1	15	2	..	4	2	4	..	12	29.5	80.7
1905	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1905	..	..	..	..	..	..	..	..	..	..	..	..	..	..	....	....
1906	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1906	..	..	..	..	..	..	..	..	..	..	..	..	..	..	....	....
1907	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	..	..	..	..	..	..	..	..	..	..	..	..	1907	..	..	..	1	..	..	1	..	..	..	1	..	..	1	4.6	81.9
1908	5	2	..	..	..	..	..	..	..	..	..	..	..	6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	..	..	..	..	1908	..	1	..	..	7	1	9	..	1	..	..	6	1	8	9.9	85.6
1909	..	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	..	1909	..	..	..	..	2	..	2	..	..	..	..	1	..	1	2.9	88.2
1910	3	..	..	..	..	..	..	..	..	..	..	..	3	..	6	..	..	1	1	1	..	..	5	..	..	1	2	3	2	2	3	1	..	4	..	..	3	..	4	5	..	..	1910	5	3	10	2	2	1	23	4	3	8	..	1	1	17	50.4	74.9
1911	..	..	..	..	..	..	3	2	..	..	..	..	..	..	..	..	..	..	..	..	6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	1911	..	1	2	..	..	1	4	..	1	1	..	..	1	3	9.2	86.1
1912	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1912	..	..	..	..	..	..	..	..	..	..	..	..	..	..	....	....
1913	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..	1913	..	..	..	..	1	..	1	..	..	..	..	1	..	1	4.6	83.5
1914	2	..	..	6	4	6	..	..	6	..	..	..	..	4	4	..	5	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1914	..	6	1	4	1	3	15	..	6	1	4	1	3	15	27.6	85.5
1915	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1915	..	..	..	..	..	..	..	..	..	..	..	..	..	..	....	....
1916	..	..	6	..	..	..	..	..	..	..	..	..	..	..	..	6	..	..	..	..	5	6	..	..	..	..	..	6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1916	..	..	..	..	1	4	5	..	..	..	..	1	4	5	16.7	86.2
1917	..	..	..	..	..	..	..	..	..	..	..	..	6	..	..	4	3	..	..	5	2	..	..	6	2	2	1	..	..	1	1	2	..	..	..	..	..	..	..	4	..	..	1917	3	4	1	2	1	2	13	2	3	1	1	1	2	10	39.7	78.3
1918	..	..	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	..	1918	..	..	1	1	..	..	2	..	..	1	..	..	..	1	0.5	82.3
1919	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	2	..	..	..	..	..	..	..	1919	..	2	..	..		..	2	..	..	..	..	..	..	..	....	....
1920	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1920	..	..	..	..	..	..	..	..	..	..	..	..	..	..	....	....
1921	..	5	5	..	..	3	4	..	..	..	..	..	..	..	..	..	..	..	..	..	3	4	..	..	..	..	..	..	..	..	..	..	..	6	..	..	..	..	..	..	..	..	1921	..	..	2	2	2	1	7	..	..	2	2	2	..	6	17.6	85.0
1922	..	..	..	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	1922	..	1	1	..	..	..	2		..	1	..	..	..	1	2.9	82.3
1923	..	6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	1923	..	1	1	..	..	1	3	..	..	1	..	..	1	2	8.7	85.2
1924	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..	..	..	..	..	2	1	..	..	..	..	..	6	6	5	..	..	1	2	6	3	6	3	5	1924	2	3	2	6	2	4	19	1	2	..	6	..	..	9	14.0	76.0
1925	..	..	..	..	3	2	1	1	2	..	..	..	2	..	..	..	..	..	..	..	..	5	4	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	..	..	5	6	1925	2	3	3	1	2	1	12	2	3	3	1	1	..	10	27.9	80.2
1926	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6	..	..	..	..	..	1926	..	..	..	..	..	1	1	..	..	..	..	..	..	..	....	....
1927	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..	1	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1927	1	..	1	..	1	..	3	1	..	1	..	1	..	3	9.7	81.8
1928	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	3	1	..	5	..	6	..	1928	1	..	1	..	2	1	5	..	..	..	..	..	..	..	....	....
1929	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	..	..	..	..	..	..	..	..	..	3	..	..	..	..	6	2	4	..	..	3	2	1	1929	1	2	2	2	..	1	8	..	..	1	1	..	..	2	10.1	80.6
1930	1	1	1	1	1	1	2	3	1	1	1	1	1	1	2	..	2	6	4	..	..	..	..	..	..	..	..	..	..	6	..	..	..	..	3	..	..	..	..	..	1	4	1930	19	3	2	2	..	2	28	18	3	1	1	..	2	25	55.9	73.7

10 different years in which the year of greatest recorded deficiency occurred in one or more States.

The distribution of the years of deficient precipitation with respect to the States, numbered in order of deficiency, is best shown in table 3, from which conditions in the different years and the different States can be readily determined. For example, in 1930 there were 25 non-arid States having deficient precipitation. In 18 of these the deficiency was of the first order, in 3 of the second, in 1 of the third, in 1 of the fourth, in none of the fifth, and in 2 of the sixth. Similar figures are given for each year. The percentage of the total area of the 36 non-arid States having deficient precipitation has been computed for each year. For example, States representing 55.9 per cent

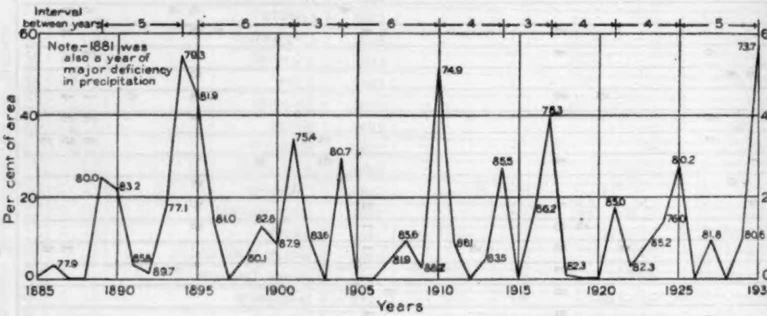

FIG. 3. PERCENTAGE OF AREA OF 36 NON-ARID STATES HAVING DEFICIENT PRECIPITATION, 1885–1930

Small figures on graph indicate ratio of deficient precipitation to mean for area affected, in per cent.

of the area of the non-arid States had deficient precipitation in 1930, and in these States the precipitation was 73.7 per cent of the mean for the 36 States. Corresponding figures are given for each year in the summary for the non-arid States included in the table, and the percentage of the total area is also indicated graphically on figure 3. This graph shows that since 1885 there have been four years of widespread major deficiencies in precipitation (including 1881, which was a year of low precipitation, makes 5 years in the last 50 years), and that there have been eight other years of marked deficiencies which were less widespread. The time interval between the years of deficient precipitation has ranged from 3 to 6 years, and 1894 and 1895 were the only two consecutive years for which there was deficient precipitation over any extensive area. The graph indicates

TABLE 4

Precipitation in 1929 and 1930 by States

STATE	MEAN FOR PERIOD OF RECORD	1929 Inches	1929 Percent of mean	1930 Inches	1930 Percent of mean	Number of months with deficient precipitation: June–Dec. 1929	1930	Jan–June 1931	25 mo. total
Non-arid:									
New England	41.70	39.55	95	34.07	82	6	7	3	16
New York	39.18	43.02	110	32.21	82	4	8	4	16
New Jersey	45.77	42.96	94	35.24	77	5	10	3	18
Pennsylvania	42.39	44.21	104	28.82	68	4	10	5	19
Maryland and Delaware	41.16	42.46	103	23.78	58	3	12	4	19
Virginia	41.78	45.92	110	25.16	60	4	12	4	20
North Carolina	49.82	62.09	124	38.04	76	3	10	4	17
South Carolina	48.10	66.13	138	40.15	83	2	8	4	14
Tennessee	49.84	59.78	120	39.79	80	2	9	6	17
Kentucky	45.47	48.46	107	27.88	61	4	10	5	19
West Virginia	42.74	46.53	109	25.43	59	5	12	3	20
Ohio	38.01	45.83	121	27.00	71	1	10	4	15
Michigan	30.53	31.22	102	22.62	74	4	9	4	17
Indiana	39.53	47.04	119	29.69	75	3	10	6	19
Illinois	37.18	41.94	113	27.89	75	3	9	5	17
Arkansas	48.31	46.10	95	46.62	96	6	6	5	17
Missouri	40.27	46.61	116	31.25	78	4	9	4	17
Iowa	31.72	30.20	95	26.10	82	4	9	6	19
Wisconsin	30.45	28.09	92	25.08	82	7	10	4	21
Minnesota	25.66	20.56	80	22.57	88	5	8	5	18
Florida	52.87	59.04	112	60.24	114	4	3	3	10
Georgia	50.08	69.83	139	46.11	92	3	7	6	16
Alabama	52.93	76.84	145	46.15	87	3	9	6	18
Mississippi	53.06	60.03	113	47.32	89	4	7	6	17
Louisiana	55.72	63.65	114	53.01	95	4	7	5	16
Oklahoma	32.65	35.39	108	30.70	94	4	6	4	14
Kansas	27.14	27.96	103	26.87	99	3	6	5	14
Nebraska	23.53	23.09	98	25.64	109	4	6	5	15
South Dakota	20.60	20.93	102	18.11	88	5	7	5	17
North Dakota	17.59	14.32	81	14.90	85	5	8	5	18

TABLE 4—*Concluded*

STATE	MEAN FOR PERIOD OF RECORD	1929		1930		NUMBER OF MONTHS WITH DEFICIENT PRECIPITATION			
		Inches	Percent of mean	Inches	Percent of mean	June–Dec. 1929	1930	Jan.–June 1931	25 mo. total
Arid:									
Texas	30.37	31.17	103	29.67	98	5	8	3	16
New Mexico	14.45	16.48	114	14.64	101	2	6	2	10
Colorado	16.77	18.16	108	17.33	103	2	7	5	14
Wyoming	14.60	15.06	103	14.68	101	5	8	5	18
Montana	15.61	13.08	84	12.37	79	6	7	6	19
Idaho	17.42	13.06	75	16.35	94	5	6	5	16
Nevada	9.02	5.83	65	9.77	108	5	5	5	15
Utah	13.10	13.60	104	15.13	115	3	6	6	15
Arizona	13.53	11.14	82	15.21	112	4	5	4	13
California	24.08	15.00	62	18.39	76	4	10	5	19
Oregon	35.00	22.79	65	22.73	65	5	10	4	19
Washington	34.00	23.67	70	27.28	80	5	10	3	18

widespread major deficiencies in precipitation may occur at intervals of 15 to 20 years and that any State is liable to have marked deficiencies in precipitation at intervals of 3 to 6 years.

Records of monthly precipitation and monthly stream flow indicate that the outstanding feature of the drought of 1930 was its long duration.

The precipitation for 1929 and 1930, with the mean for each State for the period of record and the number of months from June, 1929, to April, 1931, inclusive, when the average precipitation was below the mean, are given in table 4. By this table and graph similar to that given for Virginia in figure 2, the progress of the drought of 1930 in each State was studied and compared with its progress in other States. In most States the deficiency in monthly precipitation started in the later months of 1929 and persisted throughout 1930 and the first six months of 1931. During this period the number of months when the precipitation was below normal ranged in the different States from 8 to 20.

During 1928 and 1929 the annual rainfall was generally in excess of normal, and although deficiency in monthly rainfall appeared in later months of 1929 the indications are that at the beginning of 1930 water conditions were practically normal. Therefore the drought of 1930 can not in any large measure be attributed to conditions which occurred in preceding years.

As the precipitation began to fall below normal plant life rapidly depleted the soil water, thus leaving both vegetation and stream flow dependent on ground-water supplies supplemented by the scanty precipitation. The effect of the drought in different parts of the country varied directly with the quantity and distribution of the precipitation.

Records of stream flow (see pages 1853 to 1863) give an even better picture of the drought of 1930 in the several States and also a means for comparing it with other major droughts.

DAMAGES

General

The drought of 1930 greatly interfered with many activities, and the resulting losses were probably greater than those sustained during any previous dry period. It received more attention than past dry spells not only because of its coincidence with an economic depression, with attendant political and relief problems, but also for the more basic reason that the demand and uses for water have increased vastly even since 1910.

The damages and losses due to a drought are determined by the extent of its interference with normal activities and are indicated by the effect on vegetation, principally agricultural crops; and on water supplies as related to domestic, industrial, and recreational uses, power, irrigation, and navigation. Therefore, in determining the damages and losses of a drought in a given area many factors must be considered. Among these are the character and extent of agriculture and other activities, climatic conditions, geology, topography, and facilities for the conservation and storage of water. The whole question is so complex that it is difficult to compare the damages of droughts that occur in different areas or in different years, and any statements relative to damages should relate only to areas with definite limits, where the conditions are similar. A drought in a given locality may be detrimental to vegetation and not to water supply, and vice versa.

Vegetation

The detrimental effect of the drought of 1930 on vegetation, both natural and cultivated, was marked. No definite data are available to show the extent of damage to natural growth. Its effect on agriculture is indicated by table 5.[4] The composite yields by States given in this report are shown in figure 4, which also indicates for the non-arid States the total precipitation during the three principal growing months, June, July, and August.

TABLE 5

Composite yields by States

Yields of crops per acre in 1930, expressed as percentages of average yields secured in 10-year period, 1919–1928

STATE	CROP YIELDS AS PERCENTAGES OF 10-YEAR AVERAGES	STATE	CROP YIELDS AS PERCENTAGES OF 10-YEAR AVERAGES
Maine	101.0	North Carolina	99.4
New Hampshire	121.4	South Carolina	120.2
Vermont	112.5	Georgia	122.1
Massachusetts	115.0	Florida	98.8
Rhode Island	109.5	Kentucky	60.5
Connecticut	111.2	Tennessee	75.6
New York	99.3	Alabama	111.2
New Jersey	108.8	Mississippi	91.5
Pennsylvania	87.6	Arkansas	62.8
Ohio	79.3	Louisiana	100.3
Indiana	84.7	Oklahoma	71.2
Illinois	83.1	Texas	86.0
Michigan	83.6	Montana	70.4
Wisconsin	100.5	Idaho	109.4
Minnesota	98.7	Wyoming	96.2
Iowa	90.5	Colorado	116.3
Missouri	66.8	New Mexico	97.1
North Dakota	89.7	Arizona	117.1
South Dakota	80.6	Utah	103.7
Nebraska	105.7	Nevada	99.1
Kansas	89.8	Washington	96.5
Delaware	83.2	Oregon	113.7
Maryland	73.4	California	109.6
Virginia	67.7		
West Virginia	56.9	United States	91.1

[4] Crops and Markets, vol., No. 12, U. S. Dept. Agriculture, December, 1930.

The reports concerning the effect of the drought on crops indicate that as the yields for the country as a whole do not indicate conditions in individual States, neither do the yields for individual States indicate extreme conditions in certain localities. In many localities some crops were practically a total failure, and natural vegetation severely suffered. The areas which suffered the most are indicated in figure 5, which shows where crop shortage was so great that relief measures under the Red Cross were still necessary in February, 1931.

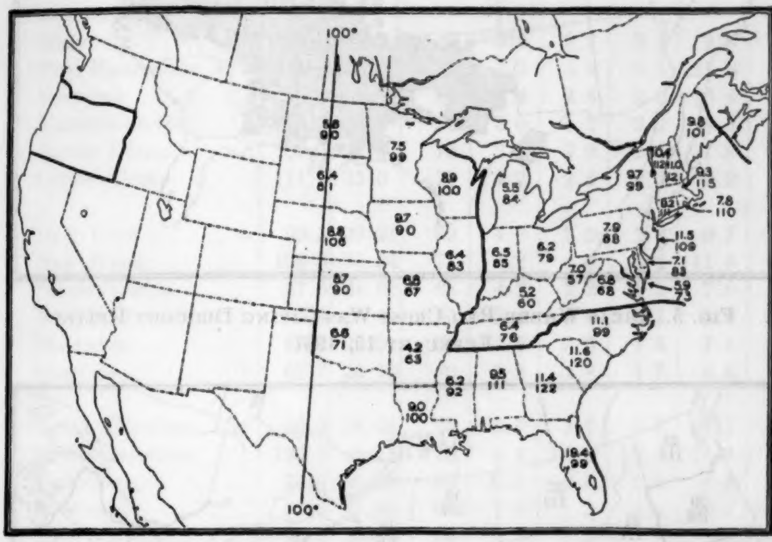

FIG. 4. TOTAL PRECIPITATION FOR JUNE, JULY, AND AUGUST, 1930 (UPPER FIGURES) AND YIELD OF CROPS PER ACRE IN 1930 (LOWER FIGURES), EXPRESSED AS PERCENTAGES OF AVERAGE YIELD, FOR STATES EAST OF THE 100TH MERIDIAN

In the area indicated by heavy outline the precipitation in 1930 was the lowest of record.

The growth of crops depends primarily upon the distribution of rainfall during the growing period. Temperature, humidity, and wind also have a marked effect. During the growing months of 1930 not only was the precipitation low but temperatures were unusually high and were accompanied by hot winds. The humidity was low, the evaporation was high, and the usual dews, which are of great benefit to vegetation, were absent. Vegetable growth was unable to withstand this combination of unfavorable climatic conditions.

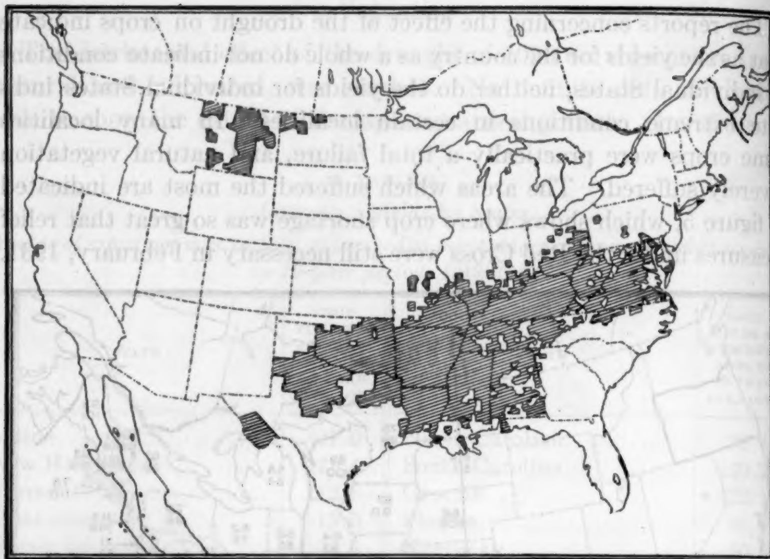

FIG. 5. AREAS WHERE RED CROSS WAS GIVING DROUGHT RELIEF FEBRUARY 15, 1931

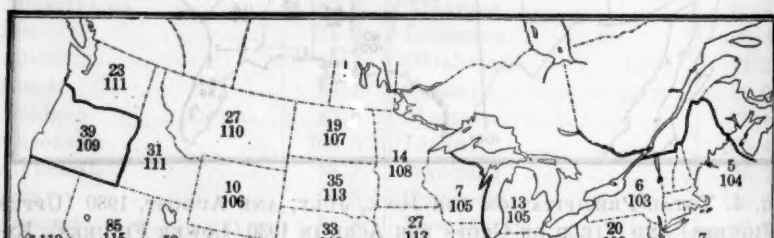

FIG. 6. NUMBER OF DAYS IN 1930 WITH MAXIMUM TEMPERATURE OF 100° OR HIGHER (UPPER FIGURES) AND MAXIMUM TEMPERATURE DURING JULY AND AUGUST, IN DEGREES (LOWER FIGURES)

In the area indicated by heavy outline the precipitation in 1930 was the lowest of record.

TABLE 6

Yields of crops per acre in 1930, expressed as percentages of average yields, 10-year period, 1919–1928 and related precipitation

STATE	CROP YIELD PER-CENT	PRECIPITATION: YEAR—1930: Inches	PRECIPITATION: YEAR—1930: Per-cent of mean	PRECIPITATION: June	PRECIPITATION: July	PRECIPITATION: August	PRECIPITATION: June, July, August: Total	PRECIPITATION: June, July, August: Average
Non-arid:								
Maine	101.0	35.6	89	3.0	3.7	3.1	9.8	3.3
New Hampshire	121.4	33.6	88	3.7	4.2	3.1	11.0	3.7
Vermont	112.5	32.9	89	4.6	3.8	2.0	10.4	3.5
Massachusetts	115.0	33.8	80	3.0	4.1	2.2	9.3	3.1
Rhode Island	109.5	32.8	76	2.4	3.0	2.4	7.8	2.6
Connecticut	111.2	35.0	77	4.2	2.4	2.6	9.2	3.1
New York	99.3	32.21	82	4.3	3.0	2.4	9.7	3.2
New Jersey	108.8	35.24	77	4.2	4.0	3.3	11.5	3.8
Pennsylvania	87.6	28.82	68	4.2	2.2	1.5	7.9	2.6
Maryland	73.4	23.4	56	3.4	1.4	1.1	5.9	2.0
Delaware	83.2	28.0	65	2.5	3.0	1.6	7.1	2.4
Virginia	67.7	25.16	60	3.3	1.8	1.7	6.8	2.3
North Carolina	99.4	38.04	76	4.7	3.7	2.7	11.1	3.7
South Carolina	120.2	40.15	83	4.4	4.8	2.4	11.6	3.9
Tennessee	75.6	39.79	80	1.4	2.4	2.6	6.4	2.1
Kentucky	60.5	27.88	61	1.8	1.2	2.2	5.2	1.7
West Virginia	56.9	25.43	59	2.9	1.9	2.2	7.0	2.3
Ohio	79.3	27.00	71	2.3	1.5	2.4	6.2	2.1
Michigan	83.6	22.62	74	3.3	1.4	0.8	5.5	1.8
Indiana	84.7	29.69	75	2.6	1.8	2.1	6.5	2.2
Illinois	83.1	27.89	75	3.4	1.0	2.0	6.4	2.1
Arkansas	62.8	46.62	96	0.9	0.7	2.6	4.2	1.4
Missouri	66.8	31.25	78	3.8	1.0	2.0	6.8	2.3
Iowa	90.5	26.10	82	5.8	1.5	2.4	9.7	3.2
Wisconsin	100.5	25.08	82	5.3	2.6	1.0	8.9	3.0
Minnesota	98.7	22.57	88	3.9	2.5	1.1	7.5	2.5
Florida	98.8	60.24	114	10.7	4.4	4.3	19.4	6.5
Georgia	122.1	46.11	92	3.8	5.7	1.9	11.4	3.8
Alabama	111.2	46.15	87	2.0	4.0	3.5	9.5	3.2
Mississippi	91.5	47.32	89	0.5	2.5	3.2	6.2	2.1

TABLE 6—*Concluded*

STATE	CROP YIELD PER-CENT	PRECIPITATION						
		YEAR—1930		June	July	August	June, July, August	
		Inches	Per-cent of mean				Total	Aver-age
Non-arid—Concluded:								
Louisiana	100.3	53.01	95	0.6	3.8	4.6	9.0	3.0
Oklahoma	71.2	30.70	94	3.8	1.0	1.8	6.6	2.2
Kansas	89.8	26.87	99	3.9	2.0	2.8	8.7	2.9
Nebraska	105.7	25.64	109	3.2	1.5	4.1	8.8	2.9
South Dakota	80.6	18.11	88	2.6	1.0	2.8	6.4	2.1
North Dakota	89.7	14.90	85	3.1	1.0	1.5	5.6	1.9
Arid:								
Texas	86.0	29.67	98	2.1	1.1	1.5	4.7	1.6
New Mexico	97.1	14.64	101	1.0	3.6	2.2	6.8	2.3
Colorado	116.3	17.33	103	0.7	3.3	3.1	7.1	2.4
Wyoming	96.2	14.68	101	1.1	1.2	3.2	5.5	1.8
Montana	70.4	12.37	79	1.5	1.0	1.0	3.5	1.2
Idaho	109.4	16.35	94	0.9	0.4	1.3	2.6	0.9
Nevada	99.1	9.77	108	0.2	0.2	0.8	1.2	0.4
Utah	103.7	15.13	115	0.4	1.2	2.6	4.2	1.4
Arizona	117.1	15.21	112	0.5	3.2	2.2	5.9	2.0
California	109.6	18.39	76	T	T	0.1	0.2	T
Oregon	113.7	22.73	65	0.8	T	0.2	1.0	0.3
Washington	96.5	27.28	80	1.5	0.1	0.2	1.8	0.6

The number of days in 1930 with maximum temperatures of 100° or higher and the maximum temperatures for July and August are shown in figure 6.

A comparison of the precipitation for June, July, and August, 1930, with the crop yields for the year is given in table 6 and on figure 7 and indicates that in States where the rainfall during the three growing months was 7½ inches or more the crop yields were nearly average or above and that where the rainfall was below 7½ inches the crop yields were below average. The few exceptions to this general rule can be explained by a study of the character of the vegetable growth and the distribution of precipitation.

The data on crop yields and precipitation for 1930 show that the annual rainfall is no indication of yields. For example, the rainfall in Arkansas in 1930 was 96 per cent of the mean. Crop yields, how-

ever, were only 63 per cent of the 10-year average, owing to the fact that there was only 4.2 inches of rain during the three growing months. On the other hand, in the New England States, New York, and New Jersey the mean annual precipitation was lower than for any other year of record, yet crop yields for all these States except

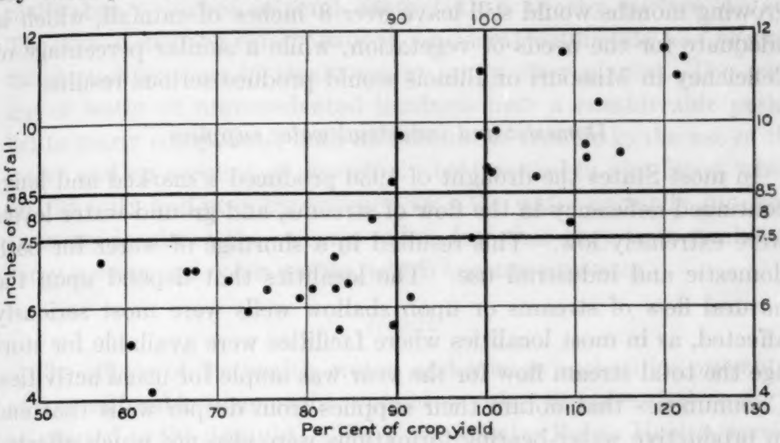

FIG. 7. RELATION OF YIELD OF CROPS PER ACRE IN 1930 TO TOTAL RAINFALL IN JUNE, JULY, AND AUGUST, 1930, FOR THE 36 NON-ARID STATES

TABLE 7

Crop yields and precipitation in North Carolina, Missouri, and Illinois, 1930

	NORTH CAROLINA	MISSOURI	ILLINOIS
Crop yield, 1930, percent of mean	99	67	83
Precipitation:			
Annual:			
Mean, inches	49.82	40.27	37.18
1930 inches	38.04	31.25	27.89
1930 per cent of mean	76	78	75
June, July, and August:			
Mean, inches	16.2	12.7	10.6
1930 inches	11.1	6.8	6.4
1930 per cent of mean	69	54	55

New York were above normal, as there were adequate rains during the growing season. In New York the yield was 99.3 per cent of the normal.

Precipitation records expressed as the percentage of mean are of but little value in showing the effect of droughts on agriculture or

other activities, as a certain percentage of deficiency will not have the same effect in an area of high precipitation as it will in an area of low precipitation. This is illustrated by the data on crop yields and precipitation for 1930 in North Carolina, Missouri, and Illinois, given in table 7. In North Carolina a 50 per cent deficiency in the growing months would still leave over 8 inches of rainfall, which is adequate for the needs of vegetation, while a similar percentage of deficiency in Missouri or Illinois would produce serious results.

Domestic and industrial water supplies

In most States the drought of 1930 produced a marked and long-continued deficiency in the flow of streams, and ground-water levels were extremely low. This resulted in a shortage of water for both domestic and industrial use. The localities that depend upon the natural flow of streams or upon shallow wells were most seriously affected, as in most localities where facilities were available for storage the total stream flow for the year was ample for usual activities. Communities that obtain their supplies from deeper wells that end in productive water-bearing formations were also not much affected by the drought.

Indications of scarcity of water appeared early in the summer. In many localities usual supplies failed, so that for several months it was necessary to haul water from distant sources. In the larger towns and cities where municipal supplies were not provided with adequate storage it was necessary to curtail use, and in many communities it was necessary to provide additional supplies by drilling wells, laying temporary pipe lines, or hauling water in tank cars. Even large cities were affected. In a survey of 110 public water supplies in Kentucky the State Board of Health reported 33 cities had been on water rations during the drought period. The Ohio State Board of Health made a survey of 115 public water supplies, of which 21 obtained their water from surface sources and 94 from wells. Acute shortages occurred at some of the surface installations but in general the supplies from wells remained satisfactory, although at a few places it was necessary to drill additional wells to deeper levels.

Many industries were handicapped by an inadequate supply of water for industrial processes and for the disposal of wastes. In many localities the provision of enough water for cooling and condensing and for steam power plants was a serious problem.

In addition to shortage of water for municipal and industrial uses, considerable difficulty was encountered in many localities owing to the effect of the drought on the quality of the water, in regard to both mineral content and pollution. During the drought period the streams were almost wholly supplied from ground water, which normally has a higher mineral content than nearby surface waters. The lack of diluting run-off caused considerable difficulty and necessitated modifications in treatment at many filter plants. The serving of water of unprecedented hardness over a considerable period led to many complaints, both on account of trouble in the use of the water and on account of deposits in heaters and in pipe lines, where no difficulty had been experienced with the water normally supplied. In many localities the streams fell so low that they were unable to carry sewage and other wastes, which became a menace.

Health

The efforts of the health, water, and sewage authorities prevented any considerable increase in typhoid or other diseases that could be attributed to the drought. The United States Public Health Service reports as follows relative to the effect of the drought on health conditions:

> Probably some of the mortality from chronic diseases and from the common respiratory diseases this winter has been due to the drought, but many factors are involved, and it is impossible to determine the exact effect of any one of the many causes which have operated to render many persons susceptible to attack by disease or weakened their resistance.
>
> During the fall of 1930 there was an increase in the prevalence of typhoid fever over the low rates for the preceding two years. Some of this increase was attributed to pollution of water supplies which resulted from low water.
>
> Two states in the drought area reported increased prevalence of pellagra during the last six months of the year 1930.

Power

The effect of the drought on water-power plants in the non-arid States is probably best indicated by a comparison of the production of electricity by means of water power for public use in 1929 and 1930 during the usual low-water periods with the total production of electricity during the same periods. At present practically all water-power plants generating electricity for public use are interconnected in large systems that include steam plants, and as the cost of operating a water-power plant is in general less than that of operating

a steam plant the water available at water-power plants during low-water periods would ordinarily be utilized to the limit.

The production of electricity in the entire United States for public use in 1930 was 1.5 per cent less in 1929. The average annual increase prior to 1930 was about 10 per cent. We have therefore this general condition—that the total production of electricity for public use in the United States in 1930 was only slightly smaller than in 1929, and it may reasonably be considered that any marked decrease in the production of electricity by the use of water power in any section would in general indicate the effect of the drought.

Table 8 shows the change in total production of electricity from 1929 to 1930 for the different sections of the non-arid portion of the

TABLE 8

Change from 1929 to 1930 in production of electricity during August to November

DIVISION	CHANGE IN TOTAL OUTPUT	CHANGE IN OUTPUT BY WATER POWER
	per cent	*per cent*
New England	−7	+4
Middle Atlantic	−2	−17
East North Central	−9	−22
West North Central	+1	−16
South Atlantic	−16	−54
East South Central	+4	−1
West South Central*	−9	+3

* Texas omitted.

United States for the four-month period August to November, which is the period of low water, and the change in the production of electricity by the use of water power during the same period.

In general the precipitation in 1929 was in excess of the mean. The effect of this excess, however, on the production of electricity by the use of water power was not large enough to distort the above comparison materially. The effect of storage tends to relieve drought conditions, but it is difficult to determine how much the situation at water-power plants was helped by the use of stored water. It is certain, however, that if there had been no storage the effect of the drought would have been much more severe and would have lasted longer, resulting in a great decrease in water-power output.

Irrigation

Except in California, Oregon, and Washington water supplies in the arid States were not especially low, and in the irrigated sections agriculture was normal, although in some localities heavy drafts were made on storage. During the year ending October 31, 1930, the amount of water in storage in 13 of 21 reservoirs of the United States Bureau of Reclamation, with a combined ultimate capacity of 10,814,500 acre-feet, was reduced 806,211 acre-feet and the storage in the 8 other reservoirs was increased by 153,957 acre-feet, making a net loss of 652,554 acre-feet.

Navigation

The Chief of Engineers, U. S. Army, reports on the effect of the drought on navigation on the inland waterway system of the Mississippi Valley as follows:

"Briefly described, the more important components of this system as now developed are the lower Mississippi, below the mouth of the Ohio, where a depth of 9 feet is maintained by dredging through the river bars; the Ohio, where a depth of 9 feet is secured by locks and dams; feeder tributaries of the Ohio including the Monongahela, the Allegheny, the Kanawha, the Cumberland, the Tennessee, and others, the most used of which are also improved by locks and dams; the middle Mississippi to above St. Louis, where the project depth of 9 feet is to be secured by contraction works and dredging; the upper Mississippi to St. Paul and Minneapolis, the immediate status of which is a 6-foot channel, obtained principally by contraction works and dredging; the Missouri, in process of improvement by contraction works to afford a depth of 6 feet; and the Illinois, in course of improvement to afford a 9-foot connection with the Great Lakes.

"The 1930 drought brought about a prolonged low-water season on these rivers, the effect of which was mitigated to some extent by the stabilized condition of low water. On the more important parts of the system navigation was kept in motion without serious interruption. Channel dredges had to be kept in operation for a much longer period than normal. On the upper reaches of some of the tributaries of the Ohio, with limited drainage areas, the evaporation, leakage, and lockage losses at the navigation dams exceeded the inflow, and the pool depths could not be maintained; but by using especial effort in preventing leakage at the dams throughout the system, supplemented by channel dredging, the navigable capacity of the Ohio and its most important feeders was well maintained. Despite heavy drafts on the reservoirs at the headwaters of the Mississippi the deficient flow in the upper Mississippi reduced the limiting channel depth to about 4½ feet.

"In summary, the effect of the 1930 drought was felt by navigation, but the consequences were not highly serious as far as navigation was concerned."

Recreation

During the last few years the use of water for recreation has greatly increased until it has now become to be recognized as a factor in the consideration of questions relating to water supply. The low water during 1930 interfered with fishing, bathing, and boating, both on account of inadequate water supply and on account of increased pollution.

Relief

In many rural localities the drought caused hardship through the failure of food, forage, and cash crops and through scarcity of water for both human beings and stock. The effect throughout the country, however, was not enough to prevent the building up of heavy surpluses of almost every agricultural product. The resultant low price levels, already beaten down by the economic depression, worked an added disadvantage on sections suffering from the drought. Because of these factors and also because the drought effects were spotty, varying widely even between adjacent counties, it is difficult to generalize. Without question, however, the drought caused much hardship, with corresponding needs for relief, especially among the "marginal" farmers, who are none too well off in the most prosperous times.

In its effect on water supplies the drought made haulage of water, sometimes in tank cars over long distances, necessary to keep stock alive. Transport of fodder also was necessary, with the alternative of moving stock out of the area affected or else selling out at a heavy loss.

Failure of cash products, whether in cotton, cattle, wheat, or corn, was the principal cause for need for drought relief. Many families dependent on cash crops, with no vegetable gardens whereby they might live directly off the land, found that low prices and depleted yield left them without sufficient means to buy the bare necessities.

Enough relief needs were traceable to the drought to bring the American Red Cross organization into action under its policy of functioning to prevent suffering due to an "act of God." A fund of $5,000,000 from the reserve and an additional $10,350,000 raised through a special campaign financed the distribution of food and clothing. The peak of this relief was reached in February, 1931, when the Red Cross was giving assistance to 460,240 families aggregating 2,000,000 persons in 850 counties in 22 States. The areas

where relief measures were conducted are shown in Figure 5. An important feature was the distribution of seeds to rural families on condition that they would cultivate food gardens in order to become self-supporting.

Drought relief funds totaling $67,000,000 were appropriated by Congress for secured loans to farmers for purposes of rehabilitation.

The areas in which Red Cross relief was necessary were in general those of marginal production and lack of diversification, both in agriculture and in other activities, which largely accounted for the inability of the people to handle the situation locally. There were other areas where the drought was fully as severe in which outside relief was not necessary. The principal causes for the need of relief due to damages by drought are well presented, though indirectly, in the Arkansas "live at home program"[5] and indicate that the real solution of the problem is to eliminate the marginal producer and to insure that each farm unit shall raise sufficient food for its own needs. Under this program Arkansas officials are working to lift the one-crop curse and persuade farmers to plant food as well as money crops so that they may be at least partly self-sustaining in time of drought. The principles of this constructive program are:

To raise grain and hay sufficient to feed all livestock.

To produce meat sufficient to supply the family's needs.

To keep enough milk cows to supply the family with an abundance of milk and butter.

To provide health insurance in the form of a year-round garden, and to preserve any surplus of home-raised vegetables.

To maintain a flock of at least 30 laying hens.

To give increased care to home orchards, and in areas where no fruit is grown at present to plant fruit trees sufficient to supply the family's needs.

To rebuild soil fertility by planting at least half the corn and cotton acreage to legumes and pasture crops.

To reduce tilled acreage and apply the surplus labor to terracing and drainage.

To inaugurate at least one home convenience and to beautify each homestead by painting all buildings, improving farm lawns, and planting flowering trees and shrubs.

To keep a budget of clothing, to study textile problems, and to buy within the income limit.

Relation of surface and subsurface waters and vegetation

The basic principles of hydrology as related to surface and ground water have an essential bearing on the effect of droughts. Vegetation

[5] See Arkansas Univ. College of Agriculture Extension Circular 255.

also is an important factor. Of the water that reaches the earth by precipitation, a part is immediately returned to the atmosphere by evaporation; another part remains on the surface, either as snow or impounded or in flowing streams, as surface water; and the remainder enters the ground and becomes subsurface water.

The quantity and distribution of both surface and subsurface waters, and also their relations to each other, are determined by a combination of factors which may be included under climate, vegetation, topography, geology, geographic location, and the works of man.

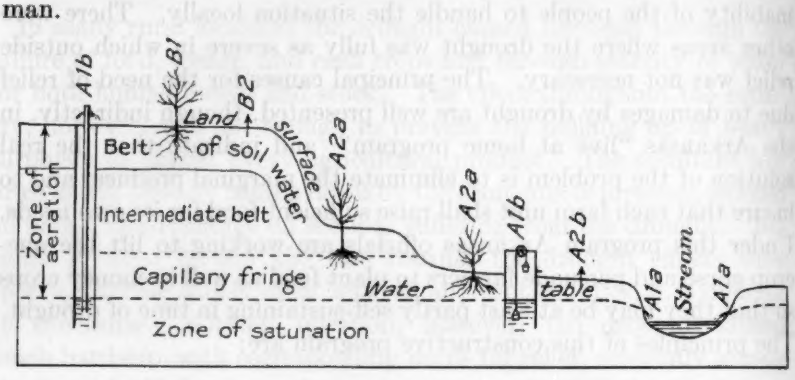

Fig. 8. Division of Subsurface Water

A 1a—Springs. *A 1b*—Wells. *A 2a*—Ground-water plants. *A 2b*—Soil which is acting like the wick of lamp in drawing water from the zone of saturation. *B 1*—Ordinary plant, the roots of which do not extend to the capillary fringe. *B 2*—Soil above the capillary fringe, which is losing moisture by evaporation.

With respect to the occurrence of subsurface water[6] the earth's crust may be divided into the zone of saturation and the zone of aeration, as indicated in figure 8. In the zone of saturation the interstices are filled with water under hydrostatic pressure. This zone constitutes the great reservoir from which stream flow is maintained and plants are, in part, fed during the periods of slight rainfall. The water in this zone is commonly called ground water. In the zone of aeration the interstices are largely filled with air. Many of the interstices in this zone contain water, and at times some of them may be completely filled. This water is not, except temporarily, under

[6] See U. S. Geol. Survey Water-Supply Papers 489, Occurrence of ground water in the United States; and 494, Outline of Ground-water hydrology, by Oscar E. Meinzer.

hydrostatic pressure and is, for the most part, held by molecular attraction, which keeps it from being rapidly drawn down by gravity to the zone of saturation. This zone acts as a distributing reservoir, and its water content is subject to rapid changes and varies considerably in amount.

The depth to the water table or upper surface of the zone of saturation varies in different localities, depending upon topography and the geologic formation. It also has seasonal variations, which depend upon the differences in the rate at which water is taken into and discharged from the zone of saturation. These variations indicate and determine the gradient of the water table, as referred to sea level. This gradient is important as related to the amount of water that is released from the zone of saturation.

The zone of aeration may be divided with respect to the occurrence and circulation of its water into the belt of soil water, the intermediate belt, and the capillary fringe.

The belt of soil water is the part of the earth's crust immediately below the surface, from which water is discharged into the atmosphere in perceptible quantities by evaporation from the soil or the action of plants. Its thickness is limited by the character of the vegetation and the texture of the earth's crust. It is essentially the same as the so-called "root zone." The capillary fringe is the belt that overlies the zone of saturation and contains interstices, some or all of which contain water that is continuous with the zone of saturation but is held above that zone by capillary action against gravity. Its thickness is determined by the texture of the material in which it occurs.

The intermediate belt is the residual part of the zone of aeration. Its thickness depends upon the depth to the water table and the thickness of the other two belts. It therefore varies in thickness and may be lacking entirely, the belt of soil moisture joining the capillary fringe. In general, the intermediate belt is of but little consequence in connection with water supplies.

The rainfall that passes below the surface first enters the belt of soil water, from which it is discharged in four ways: (1) to the atmosphere by evaporation directly from the soil; (2) to plants, which return a large portion of it to the atmosphere by transpiration; (3) to the surface water by shallow subsurface flow; (4) to the intermediate belt, through which it percolates and ultimately reaches the water table and is transferred to the zone of saturation.

Where the water table meets the earth's surface springs occur and water flows from the zone of saturation upon the land surface or into a body of surface water. Where the water table is near the surface, water may be withdrawn from the zone of saturation by evaporation directly through the soil or by plants, mostly by transpiration. Water is also withdrawn from the zone of saturation through wells, filtration ditches, and tunnels.

Plants draw their moisture primarily from the earth through their root systems and give it off by transpiration through their leaves. Root systems are particularly susceptible to the influence of changes in soil texture and moisture and are more or less modified by environment. There are wide variations in their character. Some penetrate deeply into the soil; others lie near the surface. The root systems reach out and take the water which is most easily available. Their principal source of supply is the zone of aeration. Water is drawn from the zone of saturation only where the water table is near the surface and by plants having long roots that penetrate well into the capillary fringe or below. The principal draft on the zone of saturation by vegetation is that from growth on lands adjacent to water-courses.

The precipitation reaches the surface streams either directly by flow over the surface of the ground or indirectly through the ground, either as suspended water or ground water. Low-water flows are derived from ground water; when this is supplemented by water from the zone of aeration medium flows exist, and if there is an additional contribution from the surface flood flows may be produced.

Consumptive use of water by vegetation

During the average growing season practically all the rainfall is lost through evaporation or utilized in plant growth, so that stream flow is largely dependent on ground water and low flows prevail except when the rainfall is intense or excessive.

A comparison of rainfall and run-off in the northeastern United States[7] as given in table 9 indicates that during the growing period evaporation and plant growth will consume as much as 3½ inches of rainfall a month. Therefore, unless the monthly rainfall during the growing season exceeds that amount or comes so rapidly that

[7] Hoyt, J. C., Comparison between rainfall and run-off in northeastern United States: Am. Soc. Civil Eng. Trans., vol. 59, Paper 1061, 1907.

it can not be consumed, there will be but little water available for replenishing either the surface or the ground water.

TABLE 9

Rainfall, run-off, run-off in percentage of rainfall, and loss, for the winter and the summer months, for the mean year

STATION	DECEMBER TO APRIL				JUNE, JULY, AUGUST				Total yearly loss (inches)
	Rainfall (inches)	Run-off		Loss (inches)	Rainfall (inches)	Run-off		Loss (inches)	
		Inches	Percent of rainfall			Inches	Percent of rainfall		
Connecticut River at Orford, N. H.	12.89	11.19	87	1.70	12.00	3.87	32	8.13	15.10
Housatonic River at Gaylordsville, Conn	17.80	17.12	96	0.68	16.02	5.12	32	10.90	18.43
Susquehanna River at Harrisburg, Pa.	14.48	13.58	94	0.90	12.25	2.85	23	9.40	18.29
Susquehanna River at Wilkesbarre, Pa	14.47	16.48	114	−2.01	14.00	2.74	20	11.26	16.66
Susquehanna River at Williamsport, Pa	15.48	14.76	95	0.72	12.87	3.30	26	9.57	17.76
Ohio River at Wheeling, W. Va.	16.23	15.16	93	1.07	12.61	3.12	25	9.49	19.02
Potomac River at Point of Rocks, Md	14.14	9.14	65	5.00	11.80	2.44	21	9.36	22.64
Shenandoah River at Millville, W. Va.	14.38	7.72	54	6.66	12.60	2.80	22	9.80	24.69
James River at Cartersville, Va	16.95	10.76	63	6.19	13.69	3.51	26	10.18	24.77
James River at Buchanan, Va.	15.99	10.37	65	5.62	12.87	2.97	23	9.90	24.26
North (of James) River Glasgow, Va	15.89	9.57	60	6.32	12.69	2.98	23	9.71	24.77
Appomattox River at Mattoax, Va.	16.87	9.89	59	6.98	14.36	3.05	21	11.31	26.50
Roanoke River at Roanoke, Va.	16.50	9.84	60	6.66	13.48	3.63	27	9.85	24.99
Roanoke River at Randolph, Va	17.53	9.53	54	8.00	14.60	4.62	32	9.98	25.14

Surface and subsurface water supplies are usually at a minimum at the end of the growing season, which for most sections of the United

States is about October 1. From that time until the beginning of the next growing season, about April 1, the losses through evapora-

TABLE 10

Daily maximum and minimum rate of water discharge of stream at Bryn o Dderw, Cabin John, Md., for the 28-day period September 15 to October 12, 1930

[The temperature, relative-humidity, and sunshine data were recorded by the Weather Bureau at Washington, D. C.]

DAY	QUARTS PER MINUTE		TEMPERATURE (°F.)		RELATIVE HUMIDITY PERCENT			SUNSHINE (PERCENT)
	7.00 a.m.	6.15 p.m.	Maximum	Minimum	8 a.m.	Noon	8 p.m.	
September 15	6.00	1.30	97	71	93	52	53	84
September 16	5.00	*	95	72	73	49	87	69
September 17	7.50	3.40	88	70	81	43	41	78
September 18	5.20	2.40	78	61	53	32	58	63
September 19	5.00	1.90	82	59	71	32	61	50
September 20	5.00	1.50	84	61	83	47	58	72
September 21	5.00	1.05	88	68	87	43	60	64
September 22	5.00	0.0	93	66	67	37	46	89
September 23	5.00	0.0	90	70	65	37	48	79
September 24	4.80	0.0	92	66	80	61	71	67
September 25	4.78	0.0	95	73	80	45	64	59
September 26	4.78	0.0	96	70	77	44	51	100
September 27	4.75	0.0	81	58	44	24	31	78
September 28	4.78	0.0	81	52	70	28	43	100
September 29	4.60	0.0	75	53	50	26	38	76
September 30	4.40	0.0	71	52	56	38	38	88
October 1	5.40	0.0	64	46	70	40	49	93
October 2	5.40	0.0	68	45	66	36	53	100
October 3	5.45	1.30	69	44	69	40	54	79
October 4	6.00	1.00	67	52	63	33	36	87
October 5	5.40	1.50	67	43	54	32	34	85
October 6	5.40	1.80	75	42	71	33	56	97
October 7	5.70	1.80	78	44	80	31	46	83
October 8	5.70	3.00	70	58	84	50	59	23
October 9	5.70	2.40	72	59	84	61	69	29
October 10	5.70	1.76	78	55	91	57	72	77
October 11	5.40	1.20	77	54	81	47	61	100
October 12	5.00	1.10	77	53	87	47	60	100

* Rain, 0.33 inch.

tion and plant life are comparatively small and the rainfall is mostly available for replenishing surface and subsurface supplies. October 1 may therefore be taken as the beginning of the water year.

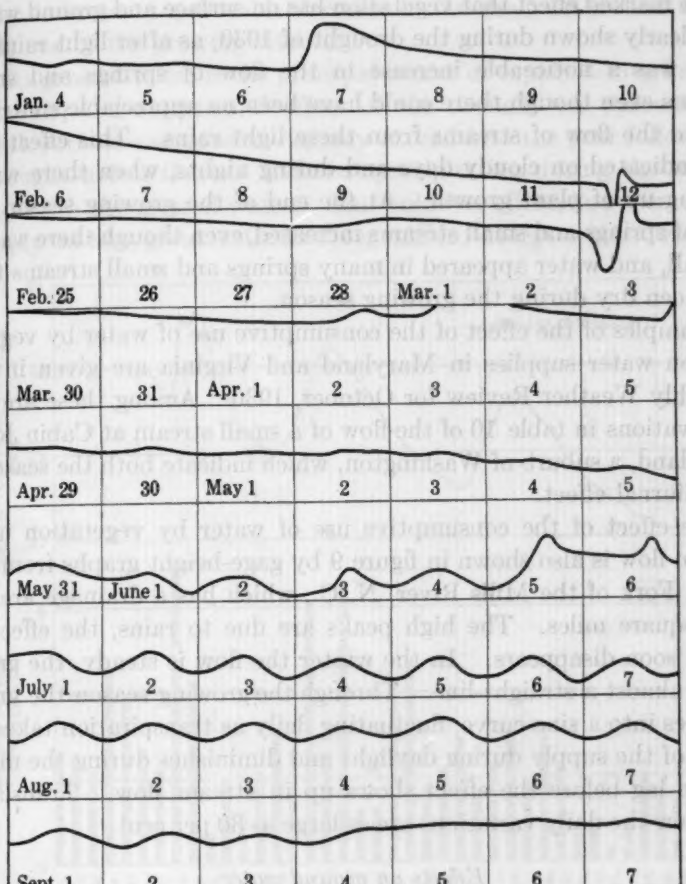

FIG. 9. GAGE-HEIGHT GRAPHS SHOWING DIURNAL AND SEASONAL EFFECT OF TRANSPIRATION OF SOUTH FORK MILLS RIVER AT PINK BEDS, N. C.

The marked effect that vegetation has on surface and ground water was clearly shown during the drought of 1930, as after light rainfalls there was a noticeable increase in the flow of springs and small streams even though there could have been no appreciable contribution to the flow of streams from these light rains. This effect was also indicated on cloudy days and during nights, when there was a slowing up of plant growth. At the end of the growing season the flow of springs and small streams increased, even though there was no rainfall, and water appeared in many springs and small streams that had been dry during the growing season.

Examples of the effect of the consumptive use of water by vegetation on water supplies in Maryland and Virginia are given in the Monthly Weather Review for October, 1930. Among these are the observations in table 10 of the flow of a small stream at Cabin John, Maryland, a suburb of Washington, which indicate both the seasonal and diurnal effect.

The effect of the consumptive use of water by vegetation upon stream flow is also shown in figure 9 by gage-height graphs from the South Fork of the Mills River, N. C., which has a drainage area of 9.87 square miles. The high peaks are due to rains, the effect of which soon disappears. In the winter the flow is steady, the graph being almost a straight-line. Through the growing season the graph changes into a sine curve, fluctuating daily as transpiration takes its share of the supply during daylight and diminishes during the night, with a lag before the effect shows up in stream flow. Translated into flow the daily variations are as large as 30 per cent.

Effects on ground water

Comparatively little data are available from which the relation of the drought to the fluctuations of ground water levels can be definitely determined. In general, however, it is known that there was a marked lowering of levels, severely effecting many localities which depend on ground water for domestic and other uses. In many localities flowing springs and wells either became intermittent or ceased to flow.

The relation of the ground-water table to precipitation is indicated in figure 10, which shows the precipitation at Washington, D. C., and the fluctuations of the water surface of a well in near-by Virginia. In 1929 and 1930 the recharge of the ground water began in January; in 1931 it did not begin until the last of March. The curve

also indicates a noticeable decrease in the draft on ground water at the end of the growing season.

As ground water is the principal source of supply during low-water periods, the detrimental effect of the drought on water supplies, both surface and subsurface, may extend into the year following the drought unless there is sufficient precipitation during the winter to replenish the ground water. This holdover effect, however, does not apply to any great extent to vegetation, except winter wheat and

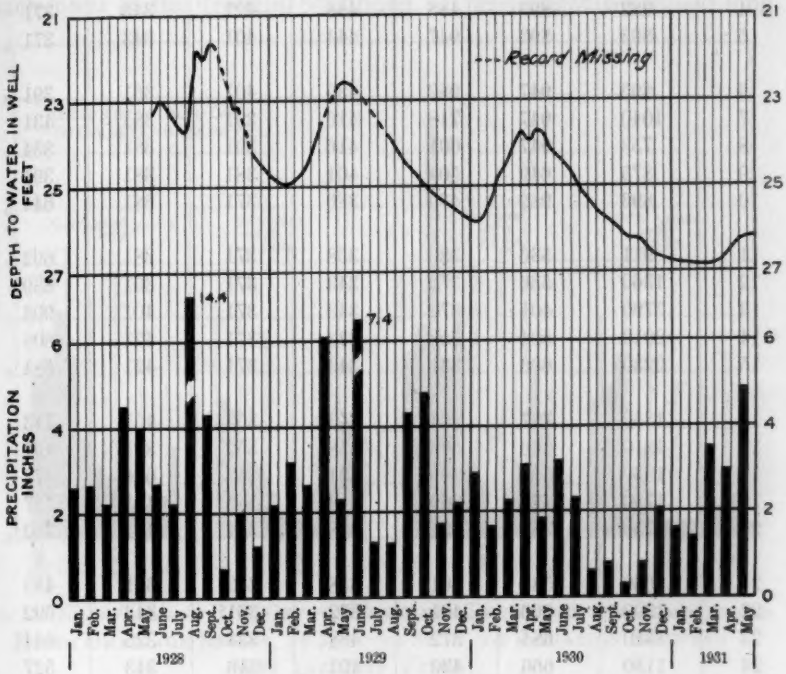

FIG. 10. PRECIPITATION AT WASHINGTON, D. C., AND FLUCTUATION OF WATER SURFACE IN ARLINGTON WELL, 1928–1931

grass, as the water content of the soil belt is normally replenished during each non-growing season, even if there is insufficient precipitation to replenish the ground water.

Effects on surface water

The effect of the drought on stream flow is of special importance from the standpoint of water supplies. The total annual flow of many streams for the year ending September 30, 1930, the year used

TABLE 11

Daily discharge, in second-feet of Potomac River at Shephardstown, W. Va., June 1 to December 31, 1930

Drainage area 5,970 square miles

DAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
1	1070	1290	617	459	441	325	401
2	982	1200	401	536	431	334	381
3	982	1050	319	459	421	334	371
4	982	893	488	488	421	343	371
5	893	893	947	444	401	343	371
6	893	947	982	430	401	361	391
7	1040	947	718	416	391	381	431
8	753	947	601	416	391	381	834
9	875	649	504	401	381	381	391
10	893	982	430	386	371	381	644
11	911	536	386	358	371	381	692
12	1360	536	372	343	371	391	889
13	3790	401	372	343	371	401	903
14	2910	504	358	343	371	421	808
15	2230	666	331	343	371	421	584
16	1850	787	294	343	352	451	743
17	1810	666	306	358	352	821	494
18	1830	536	306	331	343	644	472
19	1790	474	306	343	343	431	717
20	1750	358	331	358	334	411	730
21	1660	585	401	358	343	381	483
22	1200	666	401	372	361	343	692
23	1310	684	372	488	334	325	644
24	1180	666	430	401	316	343	527
25	1200	705	474	343	307	334	431
26	1510	294	488	331	316	361	483
27	1700	343	474	294	307	352	958
28	1070	552	459	282	307	352	930
29	1090	633	444	282	307	361	808
30	1490	568	430	282	316	361	861
31		585	444		325		808
Mean	1430	695	458	378	360	395	621

for publication of stream-flow records, did not fall below previously established minima. On the basis of the calendar year, however, many new minima were established, and in general the minimum daily flow did not fall much below that of previous years. On the other hand, the monthly flow for many streams reached new minima and many records of long-continued low flows were broken.

During 1930 minimum flows for the period of record were established on many streams as early as July, and the flow did not go much lower as the drought continued. The drought continued long

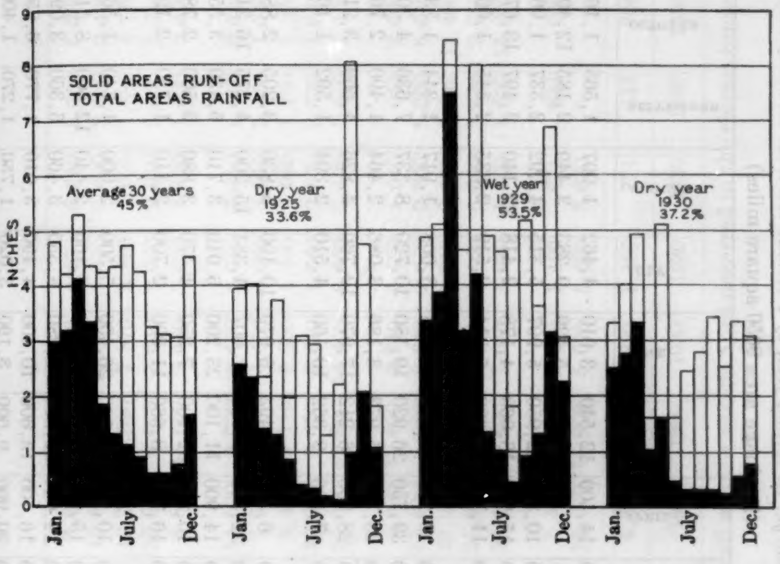

FIG. 11. RAINFALL AND RUN-OFF FOR COMBINED TENNESSEE AND CUMBERLAND RIVER DRAINAGE BASINS, BY MONTHS SHOWING VARIATION BETWEEN WET AND DRY YEARS

enough in most drainage basins to test available ground-water supplies thoroughly, and indicated that the available ground-water supply for most drainage basins is so great that it is adequate to maintain the stream flow at practically a fixed minimum without appreciable change for a considerable period of time and probably through any drought that may be expected.

The records of stream flow indicate that there is but little variation in flow during low-water periods, except that caused by surplus precipitation, and after this has reached the stream the flow soon falls to the previous minimum. This is shown in table 11 giving the daily

TABLE 12

Mean Monthly Discharge, in second-feet, of Potomac River at Point of Rocks, Md.

(Drainage area 9650 square miles)

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	MEAN
1895			24,560	14,500	12,540	3,910	4,462	1,997	1,565	1,163	1,333	2,259	
1896	5,257	10,470				5,429	9,283	3,449	2,185	12,490	6,928	4,723	
1897	4,284	42,660	20,850	10,830	22,950	5,997	5,315	4,092	2,337	1,968	2,096	6,579	10,800
1898	14,660	8,339	15,330	15,970	18,060	4,178	2,418	22,140	2,497	13,670	8,557	15,330	11,800
1899	18,680	28,130	35,240	11,750	11,600	5,314	2,519	2,335	2,345	1,663	3,171	4,068	10,600
1900	8,166	13,340	18,470	9,295	4,466	8,394	3,008	1,917	1,344	1,333	4,570	6,218	6,710
1901	4,950	3,649	13,800	39,750	26,920	19,180	10,720	8,337	7,636	4,303	4,648	25,610	14,100
1902	17,520	32,520	54,260	28,760	5,973	3,186	3,086	2,464	1,490	2,767	2,837	18,590	14,500
1903	17,200	22,190	26,730	28,900	6,212	17,970	12,760	4,826	4,669	3,212	2,175	2,926	12,500
1904	7,287	17,480	11,170	7,406	9,362	10,160	4,510	2,394	1,592	1,164	1,340	2,201	6,340
1905	8,626	5,625	23,480	6,581	4,493	6,979	10,190	5,830	3,205	2,888	2,267	10,640	7,570
1906	14,990	5,116	15,900	22,440	5,538	7,007	4,381	15,200	4,275	16,310	6,341	11,100	10,700
1907	27,000	9,560	30,500	14,900	11,100	23,200	6,010	3,710	6,430	3,550	7,850	17,800	13,500
1908	25,400	24,100	28,600	10,200	32,100	7,250	4,470	3,880	2,500	2,780	2,670	2,440	12,200
1909	6,950	11,300	8,700	16,700	8,660	11,000	2,700	2,110	1,780	2,190	1,850	3,130	6,420
1910	11,700	13,800	9,960	10,100	5,520	26,400	5,500	2,000	1,740	1,560	1,440	2,090	7,650
1911	12,200	11,300	9,670	15,100	4,330	3,690	2,160	2,440	12,600	8,510	5,970	10,200	8,180
1912	9,450	16,400	28,700	14,900	19,800	5,280	8,550	3,460	6,360	3,090	3,270	3,390	10,200
1913	11,700	5,890	18,200	16,100	13,600	10,400	4,490	3,010	1,770	6,850	13,500	8,120	9,470
1914	20,000	15,900	19,300	20,900	9,600	3,190	3,020	1,750	1,270	1,400	1,540	6,000	8,660

1915	28,600	27,000	8,230	4,370	5,900	20,400	2,670	6,760	5,350	6,730	3,590	6,650	10,500
1916	12,500	15,600	24,700	19,800	7,950	14,000	7,170	3,600	2,330	2,190	1,550	3,250	9,550
1917	9,170	7,630	38,400	10,700	5,590	7,870	3,890	2,620	1,380	4,770	3,830	2,550	8,200
1918	2,500	28,300	13,600	39,800	5,990	3,310	3,360	2,910	3,940	1,710	5,610	13,000	10,300
1919	14,800	5,980	12,700	8,860	18,300	7,130	7,220	3,130	1,720	2,420	4,620	6,880	7,810
1920	10,800	18,200	32,300	14,500	8,700	8,550	3,790	7,150	4,960	2,720	4,780	9,500	10,500
1921	6,360	6,170	12,900	4,940	20,700	4,150	4,260	3,910	3,650	1,750	4,400	11,300	7,040
1922	8,110	17,500	21,600	9,120	9,710	6,660	4,400	2,080	1,760	1,270	989	2,340	7,130
1923	6,780	12,500	10,700	10,300	5,420	2,510	1,560	2,860	3,770	1,040	2,030	6,880	5,530
1924	18,700	8,170	33,800	21,000	42,000	14,400	8,960	3,120	2,680	7,100	3,810	4,680	14,000
1925	10,400	23,600	9,680	5,990	11,300	2,710	2,420	1,580	952	2,760	6,820	5,290	6,960
1926	9,210	23,000	10,800	11,500	4,550	2,640	2,650	9,600	8,200	6,570	18,100	12,900	9,980
1927	10,700	21,600	14,500	23,200	14,000	9,420	3,210	3,110	1,540	12,400	8,400	11,800	11,100
1928	6,100	10,700	14,200	21,200	21,600	16,100	9,560	6,240	5,770	2,750	1,980	4,600	10,100
1929	4,620	8,030	24,600	27,400	14,700	7,070	3,920	1,500	1,500	15,200	13,000	7,430	10,700
1930	6,880	8,970	10,900	7,530	3,280	2,230	1,100	771	834	706	914	1,450	3,800
1931	2,370	2,930	5,400	14,200	14,200	5,610	5,520	3,630					
Minimum.........	2,370	2,930	5,400	4,370	3,280	2,230	1,100	771	834	706	914	1,450	
Minimum year....	1931	1931	1931	1915	1930	1930	1930	1930	1930	1930	1930	1930	

Note.—Minimum monthly discharge for all months except April occurred in the eleven consecutive months of May, 1930, to March, 1931, inclusive.

flow of the Potomac River at Shepherdstown, W. Va. The effect of the drought on stream flow started July 11 and continued until December 27. A minimum flow of 294 second-feet was recorded on one day each in July and August, and in September there were three days when the minimum flow was 282 second-feet. In October the minimum flow was 307 second-feet for three days and in December 371 second-feet for three days.

Low run-off in drought years is due not only to decreased rainfall but also to decreased ratio of run-off to rainfall. This is indicated in figure 11, which shows the combined flow from the Tennessee and Cumberland drainage basins as compared with the precipitation in the same area. The 30-year ratio of run-off to precipitation averages 45 per cent, but in wet years the ratio exceeds 50 per cent, and in dry years it drops to 35 per cent or less. Thus a deficiency in rainfall means a greater deficiency in stream flow.

However, a wide variation in the unit run-off of different areas is found, even in areas adjacent to each other. Observations in 1930 showed that some streams went dry, while others of comparable size in adjacent basins continued through the drought with a fair discharge. As conditions in different drainage basins are varying, estimates of low flow based on comparison with adjacent areas or on precipitation data can not be made with any known degree of certainty. Actual records of flow on the stream that is to be utilized are the only safe basis for making studies in connection with a given development and for detailed studies records of daily flow are essential. For general comparative studies, records of mean monthly flow and deficiency tables will serve most needs. Such data, for the Potomac River at Point of Rocks, Md., are presented in tables 12 and 13 as typical to show the general effect of the drought of 1930 on stream flow. Following are brief statements relative to the conditions which such tables indicate.

The conditions on the Potomac River apply in general to the areas which were most severely affected by the drought. At Point of Rocks, Md. the drainage area is 9,650 square miles, and the mean flow for the years 1897 to 1930, inclusive, was 9,560 second-feet. The mean flow for 1930 was 3,800 second-feet, or only 69 per cent of the previous lowest annual flow, which was 5,530 second-feet in 1923.

Prior to 1930 there were only two months when the mean flow was below 1,000 second-feet—September, 1925, 952 second-feet, and November, 1922, 989 second-feet. During the calendar year 1930

TABLE 13

Deficiency table for Potomac River (drainage area 9,650 square miles) at Point of Rocks, Md.

CALENDAR YEAR	NUMBER OF DAYS WITH DISCHARGE LESS THAN:										
	550	610	700	800	1,000	1,300	1,600	2,000	2,500	3,100	3,800
1897							9	29	73	107	137
1898							6	8	46	71	95
1899							23	50	115	152	172
1900						39	101	110	129	152	173
1901								2	15	60	88
1902						12	25	51	97	124	162
1903								52	60	86	113
1904					6	58	86	107	132	150	196
1905								14	37	62	130
1906										17	59
1907									2	15	57
1908							5	15	58	110	150
1909							25	112	132	163	178
1910					1	7	64	121	147	175	198
1911			1	1	1	16	24	40	51	83	109
1912								8	42	91	121
1913				1	1	4	17	29	42	69	107
1914	1	1	4	12	28	63	83	110	133	166	191
1915						1	3	6	22	72	99
1916					2	13	30	65	92	134	148
1917			1	2	6	24	45	67	94	126	167
1918						6	15	27	47	144	183
1919						9	26	48	59	87	113
1920							4	33	45	75	94
1921						6	25	47	64	96	116
1922				3	43	67	78	110	131	156	182
1923			1	12	23	38	68	102	121	153	178
1924							3	17	32	78	108
1925					21	42	63	89	111	159	182
1926							7	20	43	94	127
1927					5	15	32	39	48	82	107
1928							6	25	47	64	93
1929						16	40	62	77	85	102
1930		1	18	72	138	161	177	198	208	225	236
1931 (Jan. 1–Aug. 31)							8	29	41	68	85

the mean flow was below 1,000 second-feet for four months—August, 771; September, 834; October, 706; November, 914. The minimum daily flow for 1930 was 594 second-feet. Previous minima below 700 second-feet were recorded in 1911, 1914, and 1923. In 1923 the flow was below 1,000 second-feet consecutively for 18 days, in 1925 for 15 days, and in 1930 for 116 days except for 2 days when it did not exceed 1,100 second-feet.

During the period of record the minimum monthly discharge for all months except April occurred in 11 consecutive months May, 1930 to March, 1931. The probability of another such sequence of low-water months is remote, and therefore the years 1930 and 1931 will probably serve for some time as a basis for estimating low-water flows.

THE EFFECT OF THE DROUGHT ON WATER QUALITY

JAMES W. ARMSTRONG:[1] Baltimore receives its water supply from the Gunpowder River, which has a watershed of 306 square miles above Loch Raven Dam. The country is rolling and the hills increase in steepness as the stream nears it source. The river is fed by many springs and small streams which flow over rocks of different formation. For the most part they are of mica or Wissahickon schist, but in some localities marble and limestone are encountered.

Loch Raven Reservoir, which is the direct source of Baltimore's water supply holds 23,000,000,000 gallons of water and covers 2500 acres. An examination of the records shows that there was an abundance of water during the early part of the year 1930, but by the first of July it receded to elevation 240, which is that of the crest of the dam. From that date the reservoir level gradually dropped until on December 25th the water reached its lowest level, 15 feet below the crest. By that date 9,000,000,000 gallons of the reservoir supply had been used up. To-day the reservoir is about 4.2 feet below the crest and still lacks 2,500,000,000 gallons of being full.

On several occasions during the past few summers, I have seen the reservoir so full of organisms that they imparted a dirty green color to the water. At such times I have wondered what the water would look like in case of a long continued dry spell. We were very much surprised last summer to find that the water did not look as we expected it to, but was cleaner than usual and remained clear throughout the season.

The year 1930 was the first in which copper sulphate was applied to Loch Raven Reservoir, and for that reason it is difficult to make comparison with other years. Copper was applied to the coves at regular intervals, but not directly to the main body of the reservoir. When it is remembered that Loch Raven Reservoir holds 23,000,000,000 gallons and that during the month of June when the first taste was noticed the total volume of water withdrawn from the reservoir was not over 140,000,000 gallons per day, it can easily been seen that

[1] Filtration Engineer, Water Department, Baltimore, Md.

considerable time must elapse before any change taking place in the coves that surround the main body of water, could reach Montebello Filters.

With this thought in mind, let us look at what actually took place. For the first 15 days in April, copper sulphate was applied to the coves of Loch Raven Reservoir. Then for a period of 22 days, on account of a broken motor boat, the copper was omitted. Forty-five days after the copper was first omitted, an outbreak of Asterionella and Fragilaria reached Montebello Filters with counts ranging between 1200 to 1300 per c.c. This outbreak occurred early in June and continued until the end of the month. The total period covered about the same length of time as that in which the copper was omitted.

Another significant fact is that the residual copper for the same period dropped below 0.1 p.p.m. and immediately rose to that amount as soon as the organisms died out. During the 45 day period between the time when the application of copper ceased and the organisms appeared at Montebello, the maximum amount of water passing through the reservoir could not have been more than 6,000,000,000 gallons, or about one quarter of its total capacity.

While it is not possible to say just what movement of water takes place in a great reservoir in which the currents are very sluggish, it does not seem unreasonable to believe that there was some connection between the omission of copper and the increase in growth of organisms, especially as they ceased to appear in any numbers about the same length of time after copper was again applied.

With the exception of the increase in organisms during June there were fewer in the water than usual, especially during the latter part of the year. There were also fewer bacteria in the water than usual, and this occurred during a summer when all conditions were apparently favorable for their growth. It must have been that the copper sulphate which was applied until August 6 was responsible for inhibiting their growth.

The reason was advanced that organisms did not grow normally because the water receded below the shallow places that were favorable for their propagation and that they could not multiply in the deep water, but a study of the contour map of the reservoir revealed the fact that there was a large area of shallow water just below the surface at all elevations affected by the receding water, and there was a splendid opportunity for growth if other causes had not prevented. A second reason why the absence of shallow places favorable for

growth could have had nothing to do with the failure of the organisms to grow, is evidenced by the fact that on August 6 when the last copper was applied, the water level was only five feet below the crest of the dam and at that time only a few of the shallow places had been uncovered. Therefore, it seems reasonable to assume that the copper sulphate prevented their growth.

As previously mentioned, during the latter part of June there were great numbers of organisms, Asterionella and Fragilaria in the water. On June 20 the first taste was noticed which continued, in the presence of chlorine, until September 28, although there were very few organisms in the water after the end of June. It is believed that the application of copper to Loch Raven killed great numbers of organisms and that the release of essential oils imparted the taste that lingered so long.

It is hard to predict what might have happened in the way of increased growth of organisms if the copper had not been applied to Loch Raven. In an effort to learn something of the times when organisms might be expected to occur in great numbers, records for the past eleven years were plotted. A study of the curves indicated that the seasons had less to do with the growth of organisms than we had expected. For instance; for two years the peak occurred in January and once it occurred in April. For several years there were three or four occasions when organisms were present in unusually large numbers, but from our records it does not seem possible to predict any definite time for their occurrence, except that they seem to give more trouble in the fall. The organisms present in the greatest numbers are Melosira, Fragilaria and Asterionella.

F. C. DUGAN:[2] It should be pointed out that the year 1930 and the first two months of 1931 presented unprecedented problems to those of us who are dealing with water supplies. In Kentucky the average rainfall was only a little over 60 percent of the normal, and in certain areas it fell as low as 40 percent.

Naturally such deficiency in rainfall created unusual conditions. Unfortunately there were only a few plants in Kentucky which kept accurate records. In many of the surface water supplies the turbidity in the raw water dropped to practically zero. At Ashland in the Eastern end of the State, and which secures its supply from the Ohio

[2] Director, Bureau of Sanitary Engineering, Louisville, Ky.

River, the monthly averages of alkalinity between July 1930 and April 1931, inclusive, ranged from 25 to 62, a minimum alkalinity of 20, and a maximum alkalinity of 69. At Louisville, during the same period, the average monthly alkalinity ranged between 33 and 96, a minimum alkalinity of 23 and a maximum of 105. At Danville, which secures its supply from the Dix River or rather Herrington Lake, the average monthly alkalinity between November, 1930 and April, 1931, inclusive, ranged from 90 to 190, a minimum alkalinity of 49 and a maximum alkalinity of 216. This shows that the water in these two streams especially had a tremendous increase in alkalinity during the drought.

One of the most unusual conditions noticed in a number of the supplies was the increase in hardness. The average monthly hardness at Ashland between July, 1930 and April, 1931, inclusive, ranged from 71 to 174, a minimum of 56 and a maximum of 200. At Louisville, composite monthly samples showed a range during the same period from 78 to 154.

At Bowling Green, which secures its supply from the Barren River, the average monthly hardness ranged from 72 to 104, a minimum of 55 and a maximum of 117. It should be pointed out that Bowling Green is in the area which secured the highest percentage of rainfall in the State. It can be readily seen that the hardness, and this was chiefly sulphate hardness, was from two to three times what could normally be expected.

At practically all of the filtration plants using either surface or impounded water the amount of algae in raw water increased tremendously, and where this could not be taken care of by artificial turbidity the length of filter runs was markedly decreased. This increase in algae was also responsible for very pronounced tastes and odors in many of our surface waters. It was so pronounced that in many instances people claimed that they were unable to drink the water due to its taste and odor. These tastes and odors raised a fear in the minds of many that the water was unsafe for drinking with a result that many people used commercial and carbonated water for drinking purposes.

The bacteria count in the raw water at Louisville ranged from 14 to 56,000 per cubic centimeter and the B. coli from one to 100,000 per one hundred cubic centimeters. At Ashland the bacteria count in the raw water ranged from 3600 to 29,000 per cubic centimeter and the B. coli from 100 to 100,000 per 100 cubic centimeters.

It should be noted that during the latter part of the drought, previous to the first rains, the bacteria counts in the raw water were very low at these two cities. This would appear to indicate that the construction of the government dams in the river, with the resulting sedimentation of water, was responsible for the reduction in the count. However, after the first rains with the scouring out of the river bed, there was a marked rise in the bacteria. To summarize, it would appear that the main changes in the quality of the water were the increase in hardness and in tastes and odors.

M. S. SABIN:[3] A great deal has been said about rainfall and the lack of rainfall, but I do not think that Illinois has been given credit for having as severe a drought as she actually did have.

According to the Weather Bureau, Illinois received 73 percent of its normal rainfall for the year 1930. This is somewhat misleading, however, for two reasons. January, 1930 was a wet month, so if we drop that month and include January, 1931, that reduces the total for the State to 65 percent of its normal rainfall, which approaches Mr. Dugan's figure for Kentucky.

Another thing that should be brought out is that supplies that needed the rainfall the worst got the least. In other words, the State is divided into three divisions by the Weather Bureau, probably because of its extent North and South. The groupings of the sources also suggest similar divisions. For instance, in the Northern section, practically all the supplies are derived from rock wells, that is with the exception of the supplies on Lake Michigan. In the Central division there is a mixture of driven wells and surface supplies. In the Southern section the supplies are almost entirely surface. These divisions received the following percent of rainfall: the Northern, 78; the Central, 62; and the Southern 54.

I tried to compare what changes there were in quality during 1930 over 1929. 1929 was a year in which Illinois received a little over normal rainfall. It was not considered a wet year, however. In trying to arrive at some comparison I selected some charts representing both river and impounded supplies, and I compared the average of the results of tests made daily at the plant, for 1930 with that for 1929, for alkalinity and turbidity. Results of these tests indicated that alkalinities increased up to 150 per cent while turbidities decreased about 50 per cent during the drouth.

[3] Assistant Sanitary Engineer, State Department of Public Health, Springfield, Ill.

There seemed to be a considerable increase in tastes and odors. It is difficult to estimate just what the effect is, but I am sure there will be a decided increase in the use of methods to prevent tastes and odors. Activated carbon has been used in probably three or four plants and several plants have installed equipment to feed ammonia in connection with chlorine.

There is another effect that might be noted. During the last year we have noticed an increase in the number of private wells analyzed in the laboratory. This would indicate possibly that there is an increased interest in the safety of the water supply. We hope that this increase in interest will result in better supplies for the future so that quality will be safeguarded more in the future than in the past.

Martin E. Flentje:[4] Drought problems in Community Water Service plants were more or less problems of quantity, rather than of quality. We did have some problems, of course, but in these we were largely concerned with high concentrations of dissolved compounds usually considered undesirable rather than with harmful bacteria.

At Apollo, Pa., the water is obtained approximately 50 percent of the time from a stream known as Beaver Run. Normally this stream seldom becomes alkaline due to the presence of acid mine water, and a treatment and softening plant has been in operation since 1927. During the summer of 1930 this stream became absolutely dry, even though it has a drainage area of 42 square miles, making it necessary to run an emergency line to another badly polluted source—the Kiskiminetas River.

Many severe operating difficulties were encountered with this supply which may probably best be illustrated by the maximum concentrations of acidity and hardness in the raw water, results actually obtained on water being treated at this softening plant. We found that the maximum acidity to methyl orange, was 118 p.p.m., and that the acidity to phenolphthalein, or total acidity, was 495 p.p.m. The maximum hardness of the raw water, as measured by the soda reagent method, was 1910, and the manganese content 32 p.p.m. As high 4500 pounds of lime and 5200 pounds of soda ash per m.g. were used in a days run, and even then a plant effluent hardness below 250 p.p.m. could not be produced.

[4] Community Water Service Company, Harrisburg, Pa.

Another interesting experience, due to low water conditions, was that of the Moundsville Water Company. This company obtains its supply from relatively shallow wells in a sand and gravel bar in the Ohio River. The water obtained has always been of exceptional quality as to taste and odor, as well as bacterially, but during the summer of the 1930 serious tastes occurred. This was undoubtedly due to the presence of phenols.

While it is known, of course, that numerous shots of phenol have gone down the Ohio River from time to time, no trouble has ever before been encountered in the Moundsville supply. An explanation may be that lack of water movement in the Ohio River during the summer of 1930 either allowed unusual penetration of waste materials into the sand and gravel, or that no opportunity existed for the sand to be washed; this possibly having some effect upon the absorptive power of the sand. At any rate, Moundsville is certain that it does not like the taste of chlorinated phenols. Ammonia helped this situation a great deal.

In localities where every available supply had to be used, drought conditions led to the use of water that ordinarily would not be considered potable. This was true at Waynesburg, Pennsylvania, where one well supplied water having a chloride content of 950 p.p.m. This water was used for a period without serious complaint.

The companies that supervised during this time did not encounter any serious bacterial pollution, which was a rather remarkable thing in itself. A number of emergency supplies had to be used but in no case was a great deal of additional purification means required.

THOMAS R. LATHROP:[5] The most noticeable effects on the quality of water as a result of the drought in Ohio have been the concentration of organic and mineral constituents which have caused disagreeable tastes and odors and a marked increase in the hardness of the water. These conditions have been very marked at most of the public water supplies which are obtained from surface sources. The quality of ground waters has shown very little effect from the drought, but in some instances the water table has been lowered.

As a result of the tastes which have been experienced in many of our communities the public has sought palatable drinking water with little regard to its source. Fortunately no sickness resulted

[5] Assistant Sanitary Engineer, State Department of Health, Columbus, O.

from this practice as far as is known. This is probably due largely to the fact that most shallow wells became exhausted rather early in the period and those wells and springs which continued to flow were undoubtedly from deep and unpolluted sources.

In December and January there was considerable sickness from some intestinal disorder commonly referred to as "intestinal flu." This disease was in the nature of an epidemic in Cincinnati and at some other cities on Ohio River. It was coincident with the most severe taste condition in the water and was associated by the public and by some physicians with the bad taste in the water.

As a result of the high mineral content of the water as evidenced principally by a great increase in hardness there has been a greater interest in water softening. The hardness of many of our surface supplies reached a point in December which was about double the amount of hardness normally present in those supplies.

Specific instances of the above conditions are as follows:

The Ohio River supplies were all seriously affected by disagreeable tastes and the hardness reached 230 p.p.m. at Cincinnati in December. The average hardness is about 110 p.p.m. Ammonia-chlorine treatment was employed at East Liverpool, Marietta and Pomeroy with fair results. Tastes other than phenols, however, were not entirely eliminated. Excess lime treatment was used at Steubenville, Bellaire and Ironton. Cincinnati employed high lime treatment when taste conditions were most acute. Some beneficial results were obtained by lime treatment. This was forcibly demonstrated at Bellaire. When the supply of lime ran low for a few days in December there appeared a marked increase in tastes as soon as excess lime treatment was stopped. Supplies on the Maumee River, Defiance, Napoleon and Toledo were affected by tastes. At Defiance, ammonia-chlorine treatment was tried as a preventative measure without complete success. At Delaware, on Olentangy River, tastes were most severe ever experienced. For a period of a few days potassium permanganate was applied with good results. A rain which flushed out the river at that time made it unnecessary to continue this treatment. Upper Sandusky which is located about 20 miles below Bucyrus on the Sandusky River, obtains its water supply from the river. For several days it was necessary to cease pumping from the river to the storage reservoir on account of the large number of micro-organisms in the water. The river for ten miles above the intake was grass green in color. This condition was caused by the very slow flow of the water

near Bucyrus and its pollution with untreated sewage. A heavy shower with a considerable run-off carried the water, teeming with protozoa and algae, downstream. The extremely severe condition existed for only a few days during which it was fortunately possible for the Upper Sandusky water works to suspend pumping river water and to draw on their storage. At Columbus, which is served by two large storage reservoirs the hardness of the water before treatment was greatly increased and softening it to the usual point of 85 p.p.m. resulted in a considerably increased cost. Contamination of the Columbus reservoirs with anabaena during this period was so severe that they were treated with copper sulphate. This was the first time since the Columbus water purification plant was built in 1908 that algal conditions were so severe as to require copper sulphate treatment.

The city of Cambridge experienced a complete change in the character of its water as a result of the drought. The city normally supplied by surface water found it necessary to turn to a ground water supply. The supply for several months was very hard and had a high chloride content. It was pumped from abandoned coal mines. The water was fortunately of low acid content and by treatment in the filtration plant using high lime application a fairly acceptable water was produced, but the hardness was much greater than the regular supply even after partial softening at the filtration plant, and the chloride content was so high as to be objectionable.

Barnsville, a village of 4600 population, is supplied with water from an impounding reservoir which has a drainage area of less than 1 square mile. Its capacity had always been adequate until last year. With the reduction in the supply an effort was made to obtain well water. Several wells were drilled but the supply from ground sources was very limited and entirely inadequate. The largest consumer was a dairy which used about 25 per cent of the entire plant output. Arrangements were made with the dairy to decrease its consumption and by recirculating cooling water and by drilling a well, the use of water by this plant was reduced to a minimum. Still the public supply decreased. An emergency pipe line was laid to permit pumping from an abandoned mine into the reservoir. Analyses of water taken at the mouth of the mine indicated that it was at least usable. After pumping from the mine for a day or two it was found that water from the depths was entirely unfit for use on account of its extremely high acid content. The emergency line was then used to pump surface water from two small watersheds. From the three watersheds and

the wells the supply was still inadequate and at the time of the first rain which produced any appreciable runoff on January 5 the supply was almost exhausted. For several months all wash water was returned to the settling basins and a pump was placed to obtain the water from the reservoir bottom which was too low to permit of gravity flow to the purification plant.

Caldwell, a small village with a surface water supply for which no treatment is provided, experienced a shortage during midsummer. Wells having a high iron content were drilled which supplemented the creek supply for a short period. In the early fall the creek upstream from the village dried up and the supply was then obtained by pumping from the creek at a point below the village. The flow of the stream at this point consisted only of the sewage of the village. Enough well water was obtained for making up for normal losses. During extremely cold weather in November this emergency system had to be discontinued due to freezing of the pipe line and with the pumps shut down the sewage stopped flowing. This condition was not relieved until rains came early in January.

The village of Chesapeake which is located on the Ohio side of the river opposite Huntington, West Virginia, is supplied with water by the Huntington Water Company. Severe tastes experienced during January at many of the plants on Ohio River were apparently absent in the water at Cheseapeake. An inquiry was made at the Huntington Water Company as to how the taste was being removed and it was found that during most of the month of January activated carbon was being applied to the raw river water at a rate of about 0.35 g.p.g. This treatment was effective in preventing tastes which were very disagreeable at other points on the river.

The only ground water which has come to our attention whose quality was appreciably changed by the drought was that at Crooksville. This supply is obtained from shallow wells. Its iron content during the first year of operation of the iron removal and softening plant varied from about 70 to 90 p.p.m. During the past year the iron content gradually lowered to a minimum of about 45 p.p.m. in December. Since the first of the year there has been a gradual increase in the iron content with the increase in the ground water level.

In the water supplies affected by industrial wastes great fluctuations in the chlorine demand were noted during periods of low flow in the streams. This was undoubtedly due to the relatively small amount of dilution which the streams furnished in comparison with

the amounts of the wastes. At Warren whose supply is from Mahoning River the chlorine demand increased from 0.21 to 0.85 p.p.m. in a period of 24 hours. The drop in chlorine demand was just as rapid as its rise.

With general rains throughout the state of Ohio on January 5 and practically no evaporation during the following three months the few rains that took place during the first three months of the year contributed to the surface supplies which had been practically depleted. There was a normal rainfall in April. The first of May of this year found most of our surface supplies practically back to normal.

George D. Norcom:[6] The drought of 1930 affected the quality of a number of the water supplies operated by the Federal Water Service Corporation. In general, the mineral constituents were increased, thereby affecting the operating of softening plants. Two well supplies which are normally of good quality developed serious iron troubles. At Chester, Pa., the chloride content and other mineral constituents of the Delaware River increased many fold due to contamination by sea water. By far the most serious consequence of the drought with regard to quality was experienced at Charleston, W. Va., and it is this experience which will be discussed in detail in this paper.

At Charleston, W. Va, the Elk River flows into the larger Kanawha, and the water supply is secured from the Elk at a point about 1¼ miles above the confluence of these rivers. The Elk has a watershed of some 1500 square miles and prior to 1930 the lowest daily flow on record was 9 m.g.d. During the summer and fall of 1930 the daily flow of this river was reduced at times to 2.5 m.g.d. Gravel dredging operations in the Elk River have converted the lower stretches for a distance of over 2 miles into a long, narrow pool about 12 feet deep. There is a low dam in the Kanawha River below its confluence with the Elk which creates a backwater in both rivers for a considerable distance upstream. The sewage of the City of Charleston is discharged untreated through numerous outlets into the Kanawha and into the lower portion of the Elk below the water intake. In addition to this, the City had made a practice of dumping garbage into the Elk River at a point well below the intake. This highly putrescible material added greatly to the organic load which the river had to assimilate. Under normal conditions the flow of the Elk is down-

[6] Sanitary Engineer, Federal Water Service Corporation, New York, N. Y.

stream and the quality of the raw water at the intake is quite satisfactory for purification.

Although stream flow in the Elk River was low during the early part of 1930, the quality of the water as secured from the intake did not begin to deteriorate until early in June when the numbers of bacteria showed a decided increase. Inspection of the river showed clearly that as the stream flow in the Elk decreased, water from the lower stretches of the river was drawn toward the intake. Later this tendency became pronounced and visual observations and float tests showed that the current in the Elk was actually moving upstream.

On June 27, pre-chlorination was commenced, using doses sufficient to carry a slight residual chlorine through the filters. Unpleasant tastes and odors began to be noticeable in the treated water about the middle of July. The taste and odor was of an arometic vegetable nature, sometimes becoming quite fishy. These tastes and odors were due to several causes, chief of which were: decomposing organic matter, algae, and to some extent, industrial wastes. As would be expected, analysis of the water showed the dissolved oxygen to be decreasing and the oxygen consumed increasing.

Apparatus for feeding ammonia in solution was devised and pre-ammoniation was started on July 20 and was continued until August 1st. Various ratios of chlorine to ammonia were tried and the doses were varied over a wide range. It was finally decided that this treatment only intensified the unpleasant odor and it was discontinued.

Another experiment was tried out thoroughly during July, based on the theory that very heavy coagulation might improve the situation. Artificial turbidity was produced by the addition of clay to the raw water and heavy doses of alum were applied. Little improvement was effected by this treatment.

Microscopic examination of the water revealed many forms of plankton which are associated with unpleasant odors in water supply. During the latter part of the summer and all through the fall, a considerable section of the river was treated at regular intervals with copper sulphate applied in bags dragged by a motor boat.

The oxygen deficiency of the water became so pronounced by early August that aeration was considered essential as a part of the purification process. Temporarily, some aeration was secured by installing a grid of perforated pipes at the inlet to the coagulation basin and forcing air into the water by means of the air compressor normally used for washing filters. A new coagulation basin was in course of

construction at this plant and was completed about the middle of August. This basin was of sufficient size to give three hours retention in addition to the 6 hours available in the old basin. In view of the emergency then existing it was decided to install a more thorough aeration system in the new basin before turning it into service. Nozzles were carefully considered and discarded because the physical equipment and layout of the plant were unsuited to their use and also because of the time required for construction. The plan finally adopted consisted of bringing the raw water into the basin by means of a header at the bottom of the inlet end and extending clear across the basin. This header was provided with ten 8-inch riser pipes with their tops set about 6-inches above the water surface of the basin. Baffles were provided to prevent undue agitation. A header for compressed air was then laid along the top of the basin wall with one inch air lines running into each of the risers and extending almost to the bottom after the manner of an air lift. Compressed air at 10 pounds pressure was furnished by a Nash Hytor compressor rated at 500 cubic feet per minute. The normal pumpage at this plant being about 6.5 m.g.d., the average air applied was 0.11 cubic foot per gallon of water. In addition to this it must be remembered that the water issuing from the risers was thrown into the air about two feet with a free fall to the basin surface.

Work on this aerator was started on August 26 and the basin and aerator were completely in service on September 6, a remarkable construction achievement. Numerous tests show that this aerator consistently increased the dissolved oxygen from about 30 to about 75 percent saturation or about 150 percent. Odors escaping from the aerator were very noticeable, indicating that it was performing its function in this respect.

Just prior to the occurrence of this taste and odor trouble at Charleston, considerable success was reported by Spalding at Hackensack in the removal of taste and odor by feeding small doses of powdered activated carbon into his coagulating basins. On August 11, a dry feed machine was set up at Charleston to feed into the coagulated water and a dose of 20 pounds per m.g. of Nuchar No. 2 was applied to the water as it entered the filters. Within a few hours all of the filters were showing maximum loss of head and, it being impossible to wash them rapidly enough to keep up the supply, the carbon feed was discontinued at that point. During this treatment the filter effluent showed some improvement in taste, but the results were by no means perfect.

The next day the point of carbon application was moved to the inlet of the coagulation basin and the same dose applied there. The improvement was so slight that the dose was gradually increased to 40 pounds per m.g. Observers were not in entire agreement as to the benefits secured, some stoutly maintaining that there was no improvement whatever. I believe it is a fair statement to say that a slight improvement was effected by this treatment. The carbon feed was continued until the end of the emergency. After the second basin became available, a split carbon treatment was tried with no apparent improvement in the results.

On September 22 an additional treatment for odor and taste was instituted consisting of superchlorination and de-chlorination with sulphur dioxide. Doses of chlorine heavy enough to produce a residual of from 2 to 4 p.p.m. after sedimentation were used and the the water was dechlorinated just prior to filtration to a residual of 0.5 p.p.m. An immediate improvement was noted and this process was continued in service for about a month when the character of the taste in the water suddenly changed for the worse. Experiments indicated that the super and de-chlorination were intensifying the taste, probably due to the addition of sulphur. This treatment was then discontinued and the plant was put back on straight pre-chlorination with improved results.

Among the treatments tried during this emergency may be mentioned the addition of a coagulating dose of alum to the river over a section two miles long on two different occasions. This section of of river was also treated with hypochlorite of lime on several occasions in addition to the copper sulphate treatments already mentioned.

A Wallace & Tiernan Ammoniator was purchased about October 30 and a number of carefully controlled experiments were carried out on the plant, using chlorine with ammonia. The results were not encouraging.

Throughout the emergency, numerous laboratory experiments were carried out either in connection with the above described treatments or along lines of independent research. The use of potassium permanganate and the excess lime method were carefully investigated and discarded.

In order to avoid confusion, I would like to point out that the above described treatments on a plant scale were not tried independently, but in conjunction with each other so that at times two or three methods were in use at the same time.

During the greater part of this emergency, a small experimental filter containing 30 inches of Hydro-darco was in constant operation on the plant effluent at a rate of 2 gallons per square foot per minute. This unit removed all of the taste and odor from the water except on a few occasions when an odor of intensity "1" was detected.

In connection with the above discussion it is important to know that at all times the bacteriological quality of the water delivered to Charleston is subject to a daily triple check. In addition to the routine examination made by the plant chemist, independent samples are examined each day by the City Chemist and by the Laboratory of the State Department of Health. On no occasion during the emergency did the water fail to pass the revised Treasury Standard by any of these tests.

The situation at Charleston persisted so long that it was finally decided to construct an emergency intake to the Kanawha River just above Charleston. While the water in this stream was far from ideal, it was superior to that of the Elk. This job consisted in the construction of a 24-inch river intake, 240 feet long, the installation of a 10 m.g.d. pump, the laying of 6,000 feet of 20-inch C. I. pipe on land and 825 feet of 24-inch Universal pipe under the river and the connecting of this line with the piping at the filter plant. This job was started November 17 and finished December 24, a total of 38 working days. This emergency line was tested and operated for one day only. By December 24 the flow in the Elk had increased to such an extent as to end the emergency and establish normal conditions.

CHARLES E. TROWBRIDGE:[7] Of the forty-three water works systems operated by the American Water Works & Electric Company, thirty-six obtain a supply from a surface source. Some of these plants are located within the area where the drought of 1930 was most severe.

As the dry weather period progressed to break all previous records, the quantity of water available for many public supplies was very materially reduced. In other cases where the water was drawn from surface sources, the quality of the water was seriously impaired. Eleven of the plants in the group I have referred to experienced difficulties of one form or another in their purification treatment due to the effect of the drought upon the quality of the raw water. These troubles were caused principally by the presence of objectionable

[7] American Water Works and Electric Company, New York, N. Y.

taste and odor producing substances in the raw water. In some instances, however, extreme hardness and high salt content due to the concentration of these minerals in the low flows of the streams gave trouble also.

Climatic and other conditions which make for luxuriant growths of algae were prevelant last year. The microscopic plant life multiplied with amazing rapidity in some impounded waters where daily examinations are made. Early in the year the regular established treatments for the prevention of algae tastes and odors in the filtered water, which had proved to be successful over a period of years under ordinary conditions, had to be replaced by extraordinary methods of control and treatment. Similar heavy growths of algae were later washed into the streams by the first light fall rains and with other decomposed organic matter imparted a bitter woody taste to the water which was difficult to remove.

The taste and odor producing substances in the streams and impounded waters came mainly from vegetation, but in some streams, industrial and other wastes added to the difficulties of water purification.

The flow of the Monongahela River became so small it was not sufficient to maintain the pool levels required for navigation. Arrangement was made by the Government for the release of sufficient water from the storage in Lake Lynn on the Cheat River from time to time to fill the pools on the Monongahela. The Lake Lynn water was filled with algae which was promptly killed when the water mingled with the acid mine drainage entering the river from other tributaries. A most disagreeable taste and odor was produced which could not be removed completely by ordinary purification methods. Fortunately, we had available the treatment using activated carbon and an effluent water free from taste and odor was obtained through its use.

A similar artificial flow was produced in the Allegheny River in November by releasing water from a pool on the Clarion River. In this case the water released contained large quantites of industrial wastes, and the entire flow of the river was highly discolored for several weeks. Treatments of eight and nine grains of alum were required to remove the color. A "musty" "woody" taste was also present in the river water.

The effect of the acid mine drainage in the dry weather flow of the streams was to greatly increase the hardness of the water. For ex-

ample, the Monongahela River at Elizabeth reached a peak of hardness double any previous record. In cases where the water is softened the costs of softening were increased in the same proportion. In recent years it has become the practice of some industries located on streams which are acid due to mine drainage, to neutralize the mineral acidity of the water pumped for cooling purposes by adding lime. During the low flow of the Monongahela River last year large quantities of lime were used for this purpose with the result that the the character of the whole river was changed and all of the acidity neutralized.

The experiences of the 1930 drought have made possible the testing of some of the newer methods of water treatment, particularly in reference to taste and odor removal. It has also brought out clearly the importance of each of the well established practices in water purification. Even with all of these facilities available for the protection of public water supplies, it is evident that more attention must be given to the protection of the streams from pollution by domestic and industrial wastes which have not had proper treatment.

H. E. MOSES:[8] Pennsylvania was on the eastern fringe of the States affected by the 1930 drought and did not suffer with the same severity as many of the other States in this section. Nevertheless, the State was considerably affected. The entire State was not affected equally, the drought being most severe in the southern half, except in the Philadelphia district, and the western third. Elsewhere there were localities affected, but in general, the drought area was confined to the section just described.

The drought started in May, became intensified by the end of July, reached what was thought to be the peak in August, diminished somewhat in September, but in October made a fresh start and continued up into 1931.

Pennsylvania has an average of 42 inches of rain each year but during 1930 there was a deficiency noted in nearly every one of the 70 recording stations. This ranged from 1.92 inches at Montrose in the northeastern part of the State to a maximum deficiency of 23.94 inches at Somerset in the southwestern section.

Naturally, the streams reflected the lack of rainfall, the smaller ones drying up completely and the larger rivers and main tributaries showing the lowest flow of record.

[8] Assistant Chief Engineer, State Department of Health, Harrisburg, Pa.

The public waterworks on the large streams in general did not suffer from lack of supply, although the raw water itself oft-times left much to be desired from the standpoint of palatability. This was particularly true along the Monongahela River and the waterworks officials were frequently in desperate straits to produce a water which the public could drink.

On the other hand, the public water supplies on small streams and using underground sources were seriously affected, for the normal supplies frequently were depleted and the waterworks officials were obliged to exercise their utmost ingenuity to maintain service.

This situation is well set forth in the fact that in 48 counties, more than half the entire State, 125 communities were obliged to use either auxiliary, emergency supplies or both. In 41 counties, there were 97 places where the normal supply practically failed and emergency supplies were resorted to.

Water was secured wherever it could be found. To this end, use was made of surface streams, wells were drilled, spring water was turned into the systems and the flow from mines was used in several instances where other supplies had completely failed.

One instance occurred where a two and one-half mile pipe line was laid on the ground to pump water to a filter plant to augment an almost exhausted supply. Here also the wash water from a filter plant was pumped back to the sedimentation basin. Waste condensor water, temperature 125°F. was pumped directly into the distribution system. Pumps were installed on wells long unused and operated while there was any water to pump. A pump driven by a tractor was placed on the river bank. In one extreme case, water from drilled wells was pumped into temporary aeration racks. Again a stream containing mine drainage was treated with lime in the stream bed to neutralize the acidity and then filtered through a tub filter set up on the bank of the stream.

All these supplies had to be protected. To accomplish this, emergency chlorinators, mostly barrels using hypo, were set up on every unfiltered supply and in all kinds of places. One was placed at a well out in a cornfield, another in a tannery extract works and still another in a milk plant, and so on.

The Department of Health put five mobile laboratories into the field in order to make prompt check on emergency public supplies, but principally to render service in rural sections where the springs and wells used on farms and in villages had either failed or were sadly

depleted. In connection with the failure of one public supply, examination was made of private supplies over a radius of 20 miles from this community, 700 samples being collected and examined in this one district.

The laboratory work started in July and continued until the end of the year. It was carried on in 40 counties and a total of approximately 5,000 water supplies were examined, mostly from private sources.

The Secretary of Health, through the Press, warned the public to exercise care in the use of unknown supplies. He urged conservation measures where public supplies were low. Efforts were made to give the precautionary advice the fullest publicity. Handbills were distributed, newspapers carried the story, and in many acute areas announcements were made in the churches and through the movie houses. A criterion of the effect of this work may be sought in the records of typhoid fever. Although typhoid fever increased last fall, there was no outbreak which could be attributed to any normal or emergency public water supply.

INSTALLING AN ACCOUNTING SYSTEM IN A SMALL PLANT

By Ralph A. Hoot[1]

For the past two and a half years I have been a rambling free-lance water works engineer specializing in placing filter plants in operation. During this interval I have installed a number of water works accounting systems in towns varying from 3,000 to 20,000 in population.

In Michigan there is a decided need for an accounting service such as I have offered. Certainly the accounting of many of our smaller water works is obsolete and more or less meaningless. However, if I were asked if a success could be made of selling such an accounting service I would answer emphatically, "No"; certainly not under our present economic conditions. In general, our city officials readily admit the laxness of their water plant accounting and the need for rehabilitation, but when it comes to direct action on paying for the up-to-date system, they balk, unmoveably.

The one thing which has most impressed me in these two and a half years, and, this I suppose most of you realize, is that most bookkeepers in smaller towns have little conception of double-entry accounting. Most of them merely do the routine billing, leaving the closing of the books and the preparation of the statements to the visiting accountant.

To me, the water works bookkeeper should do all the accounting routine, including the preparation of the trial balance sheet and operating statements, and an accountant only should audit the books once each year. Thus, where I have installed systems I have followed an installation and instruction plan in which I install the system and then teach the worker its fundamentals by spending a day a month for a year supervising the work. At the end of the year the routine employee should be able to carry on alone.

In installing an accounting system in a small plant I usually follow seven distinct steps. The first of these is to outline the financial policy of the department. This involves determining whether the

[1] Water Works Engineer, Detroit, Mich.

taxpayer or water consumer owns the department, that is, whether capital and interests cost shall be paid for from water revenues, whether the department shall receive credit for fire protection cost, and whether depreciation shall be considered. I am speaking here, of course, of a publicly owned utility.

An example of a financial policy is as follows: "Resolved, (1) that this water department shall be considered as owned by the taxpayer and that the interest and principal on the bonded indebtedness shall be paid from general taxation, (2) that the water department shall furnish, free, the water for fire protection, (3) that depreciation shall not be considered as a charge against the department, and (4) that all revenues in excess of expenses shall be carried to the surplus account, and an analysis of this account clearly presented in the annual report."

Please note that I do not sanction such a policy as the ideal one. I do, however, believe it is good business to have a clear understanding of just what the water department is supposed to do. Such a statement might well be included in most of our municipal department reports.

The second step of the accounting installation is the preparation of the initial balance sheet from the information available. This may or may not be meaningles, depending upon the past records of the utility, but it at least serves as a working basis.

The next step is to outline or prepare the general ledger, the asset, liability, revenue and expense accounts, and the special books, the cash received register, cash deposited register, voucher register and payroll register. These four special books usually suffice, assuming the form of the consumers ledger is satisfactory.

The fourth step is to prepare a standard procedure or guide book, similiar, to our U. C. of A. book, so the routine worker will have a written record of what to debit and credit to the respective accounts. This guide book I feel is very necessary.

The following step is to prepare the purchase order, preferably in triplicate, and establish a hard and fast rule that all purchases must be made by order and ratified by the superintendent. A good purchase system, I might add, is the centre of gravity of any accounting system.

All that has been done so far is preliminary in nature, and in the next step comes the actual teaching of the routine employee. This, as I have said, consists of brief instructions on the routine work and

then returning at the end of each month for a year to aid in the closing work, the preparation of the statements and statistics. By such a service plan I have taken middle aged women who previously had done nothing more than prepare bills, and transformed them into quite capable bookkeepers; sufficiently capable that they could carry on alone.

The closing step of the installation comes at the end of the year with the preparation of a report giving, of course, the income statement and showing the comparative balance sheet, the new with the old or basic one. The introductory summary to one of my reports, read, in part, as follows:

"During the year total revenues were $60,000, total expenses $48,000, leaving a net revenue, or apparent profit, of $12,000. This sum, in accordance with your financial policy, has been carried as an addition to surplus."

"An analysis of this surplus figure shows that $7,000 was reinvested in line extensions, $2,000 in improvements to the existing plant which are quite permanent in nature and considered, therefore, as capital improvements, $1,400 in consumers bills unpaid, $600 in pipe purchased and on hand, $400 in alum purchased and on hand $300 in prepaid insurance, and $300 increase in cash."

WHAT ARE THE ADVANTAGES OF STUB ACCOUNTING?

By Lawrence M. Bailey[1]

During the last few years the system of customers accounting, generally referred to as the "Stub Accounting Plan," has been steadily gaining in favor in all types of public utilities. In the telephone accounting field it is almost the universal system. Among gas and electric utilities it has been adopted by the majority of companies billing over 7500 accounts per month. Recent surveys among water utilities have shown a definite trend toward the adoption of this plan during the past three years in preference to other methods of handling the customer accounting work. Of course, this is more generally true among companies which have changed from their former hand method to mechanical methods of bookkeeping and billing, although many have changed to Stub Plan from other plans which utilized mechanical equipment.

Although the stub plan has been successfully used on the hand method, the development and application of mechanical equipment to the customer billing work has no doubt been responsible for the increased use of this plan. Several types of machines have been developed which can more economically handle the complete billing and debit posting job, using stub plan, than if other plans were adopted.

The following figures are of interest in showing the extraordinary growth of the number of stub plans in use among water utilities for the period prior to December 31, 1927, and the last three years. A survey of 221 water utilities using mechanical methods of billing showed that 76 percent were using Bill and Ledger Plan as of December 31, 1927; 22 percent used Stub Plan, and 4 percent used Register Sheet Plan. During the period from 1927 to 1930 inclusive, 192 water utilities adopting mechanical methods of billing for the first time, 45 percent of the installations were the Bill and Ledger Plan, 54 percent the Stub Plan and 1 percent the Register Sheet Plan. Therefore out of a grand total of 415 companies we find that 61 per-

[1] City Controller and Superintendent, Water Department, Lincoln Park, Mich.

cent are using the Bill and Ledger Plan, 36 percent the Stub Plan, and 3 percent the Register Sheet Plan. Comparing these figures with the percentages at the end of 1927, a remarkable increase appears in the use of the stub plan where mechanical accounting is present.

The purpose of this paper is to point out some of the advantages which are claimed by the exponents of this plan, over any other method of handling the customers accounting work.

It is claimed that the stub plan is the most economical plan for handling revenue accounting, when the unit cost per meter billed is compared with the cost under other plans. In order to substantiate this claim, it is necessary to analyze the different steps of the work and point out the manner in which the stub plan lends itself to effecting this economy.

1. Expensive ledger records, indexes, and filing equipment are unnecessary.

2. Rewriting of ledgers at intervals is avoided, therefore, saving both labor and material costs.

3. The ledger record, being a part of the bill form, is easily addressed, and the debits are posted as a by-product of the machine operation, on some types of mechanical billing equipment.

4. In billing, only one form has to be considered and much time is saved in handling as compared with posting both a bill and ledger.

5. Posting to the wrong account in making the bill is practically eliminated.

6. Duplication of information carried on both the ledger and the meter book is eliminated.

7. Although more data must be carried on the meter reading sheet, this sheet, being the original book of entry, must be referred to eventually in cases of complaints on readings, and the direct reference eliminates the examination of intermediate records, which is the ordinary practice, if such records are available.

8. The stub plan is more flexible than any other plan, as a unit ledger for each billing period is provided.

9. It is claimed that the handling of all final, late or special bills is easier under the stub plan.

10. The records being in unit form, may be easily re-arranged and transfers between controls, etc., are more readily effected.

11. One of the principal advantages claimed is in handling the credit posting work. As payments are made, the cashier's stubs

are compared daily with the unpaid ledger stubs, which may be pulled from the active file, posted and summarized, and the totals reconciled with the cashier's report. If all paid stubs are then filed together, the balance of stubs in the current file will represent the unpaid accounts, and at the end of any period the Accounts Receivable may be balanced very readily and quickly, as all unpaid accounts are in one continuous file.

12. As the majority of customer accounting department employees are now women, the stub plan has advantages in the fact that heavy binders and ledger trays are eliminated, and it is usually unnecessary to transport any of the files.

13. As there are nothing but open items to handle, the taking of a trial balance and preparing collection notices is simpler and faster.

14. Having a unit ledger for each billing period facilitates the compiling of statistical information concerning revenue classifications, consumption, and such other statistical data as may be necessary.

15. Unpaid balances are carried forward to the next month's ledger stub and delinquent balances may be detailed on the new ledger stub if necessary. This provides sufficient credit information.

16. If additional credit information is necessary, it can be noted on the meter reading records, which are as available for reference as any other form of ledger might be.

The chief disadvantages of the stub plan perhaps should also be mentioned.

1. No continuous record of the customer's debits, credits, and balances is available. In order to have a statement of a particular customer, showing the amounts and dates of payment for a period, it is necessary to refer to several monthly files. Although much of this information may be obtained from the meter sheet, many companies have refused to sacrifice this valuable feature of the ledger plan.

2. More and better supervision is required to operate properly the stub plan, as compared with the ledger plan. The small paper stubs may become misfiled or lost, causing considerable difficulty at the time of taking the trial balance.

3. Although it is claimed the stub plan enables a billing to be done more economically, on the common types of mechanical equipment used in this work, recent developments in some types of machines have reduced the margin of cost between stub and bill and ledger plan to a rather small item.

4. Although many small utilities are using the stub plan, it is claimed that the margin of economies of the stub plan and other plans is large only when a considerable number of accounts are billed monthly.

5. Some of the advantages claimed for the stub plan in posting cash, trial balancing, and follow up of delinquents can also be applied to the ledger plan. If the ledger is in loose card form, the paid ledger accounts may be withdrawn and filed immediately behind the unpaid accounts. Thus at all times the card file contains only ledger cards which have open accounts. Of course, this necessitates refiling the unpaid ledger records in the paid file before the next billing period. However, this plan has been successfully used by utilities which do not have a very large percentage of delinquent balances to be carried forward on to the next bill.

The number of companies adopting the Stub Plan during the past few years, leads to the conclusions that it is the consensus of opinion among the accounting officials in this group that the economies effected by the stub plan outweigh its disadvantages. Although the opponents and proponents of this plan of customer accounting will probably continue to discuss its merits and demerits a long time to come, it certainly has established itself as a workable and economical manner of handling the customer accounting problem.

TABULATING MACHINES IN CUSTOMER ACCOUNTING

By John H. Kimball[1] and R. M. Sedgwick[2]

East Bay Municipal Utility District is a municipal corporation of the State of California, deriving its authority from the state by special enabling act of the legislature. It comprises the following nine cities located on the eastern shore of San Francisco Bay: Richmond, El Cerrito, Albany, Berkeley, Emeryville, Piedmont, Oakland, Alameda and San Leandro, with a total population of over 500,000.

The District is, however, a separate municpal entity entirely independent of the municipal governments of any of the cities which comprise it. The government is vested in a Board of five directors, elected at large, who serve for a nominal consideration.

The district was formed in 1923 for the special purpose of developing and furnishing an adequate water supply for the East Bay cities, and in 1925 commenced the construction of a water supply project on the Mokulumne River, building for diversion purposes a concrete gravity arch dam of approximately 68½ billion gallons storage capacity. This dam, known as "Pardee Dam," is located about thirty-five miles northeast from the city of Stockton, California.

The water is transmitted to the District through steel pipe lines, concrete pipe lines and tunnels of a total of approximately ninety miles. The initial transmission lines were constructed with a capacity of 60 m.g.d.; tunnels were constructed, however, for an ultimate capacity of 200 m.g.d.

On December 8, 1928, the District acquired the entire properties and assets of East Bay Water Company, which company was until that time, engaged in serving the district with water from local sources of supply. It was the inadequacy of such local supply to meet the rapidly growing needs which first led to the formation of the District.

[1] Accountant-Secretary, East Bay Municipal Utility District, Oakland, Calif.

[2] Assistant Accountant-Secretary, East Bay Municipal Utility District, Oakland, Calif.

As at January 1, 1931, the District had in excess of 129,000 water consumers—100 percent metered. Bills are rendered monthly against each consumer for the amount due, based on the monthly consumption registered by the meter plus a service charge.

The monthly reading of meters, rendering of bills against consumers and the keeping of accounts with all consumers is done in the "Consumers Accounting Bureau" under the direction of the Accountant-Secretary of the District and under the personal supervision of the Assistant Accountant-Secretary.

TABULATING MACHINES AND CUSTOMER ACCOUNTING

The use of tabulating cards as the basis of a system of customer accounting is not new. In 1916 East Bay Water Company of Oakland, California, installed probably the first system making use of this equipment in connection with customers' accounts. At that time the Water Company served approximately 65,000 consumers.

In 1928 when East Bay Municipal Utility District was about to take over the privately owned Company, an extensive study was conducted inquiring into all modern methods of customer accounting as observed by the larger public utilities. Without entering into a discussion as to the comparative merits of any of the available means of keeping customers' accounts, it may be said that the District approved this fundamental system used by the Water Company, expanding it to meet its growing needs and installing improved equipment perfected by the manufacturer.

While this method of handling customers' accounts has not become general as yet, we are informed that a growing number of the larger utilities in different parts of the United States have lately adopted systems which correspond to that used by East Bay Municipal Utility District with modifications to meet their particular local problems. These recent installations have been made in both publicly and privately owned utilities and cover a combination of utility services such as water and power or light and gas, as well as a single service such as water.

The increasing use of tabulating equipment in connection with customer accounting among the utility organizations of the country is presumptive evidence of the merit of this system.

Although the basic principles of customer accounting by means of tabulating cards are the same at this date as they were in 1916 when the adaptation of the machines for such purposes was first made,

several supplementary machines, designed for special functions, have been recently perfected, materially increasing the value of the system from an accounting standpoint.

Among these might be mentioned, first, the development of the bill printing tabulator which automatically prints on a pre-addressographed bill the information as to meter readings, consumption and amount due previously recorded on the punched cards. This punched record contained on the card becomes in the machine a printed record on the bill. Another new machine is called the "interpreter," which prints upon the margin of a tabulating card the information punched into that card so that the reading of the information punched in the card no longer requires any particular training on the part of the clerical force.

For the benefit of those of you who may not be familiar with the scheme, the following brief outline is given.

It is first necessary to understand that a tabulating card is the basis of "punched hole accounting," and that information of any character which can be reduced to numerals is punched into the tabulating cards, utilizing a particular field of all cards for one character of information. After punching, the cards can be sorted by means of the tabulating equipment into any order in accordance with the holes punched in them, and thereafter can be tabulated to give totals of any of the items punched into a group of cards. These totals are produced automatically on tabulations which correspond to lists made by any other mechanical means.

As a basis for customer accounting, a tabulating card is pre-addressographed for each consumer each month and the information as to account number, present meter reading, prior meter reading, consumption and the amount due is punched into each card from the original information shown by the meter reader's record.

After being so punched and the work checked, the cards are utilized to print upon a corresponding pre-addressographed bill the information which is punched into the card, thereby producing a bill for presentation to the customer by purely mechanical means. During the same operation such office record of the billing as is desired can be prepared as a portion of the bill. Unpaid prior months' accounts are automatically added by utilizing the corresponding unpaid cards. These delinquent charges appear by monthly items and in total upon the one bill.

Subsequent to this billing, the tabulating cards may be tabulated

to give statistics as to character of revenue and consumption of water, or other service furnished by the utility.

Later the tabulating cards themselves constitute the ledger of accounts outstanding against consumers. Debits are posted to this ledger by the mere addition of punched cards to the unpaid card files. Credits are posted by removing the punched cards from the unpaid files, after which they are tabulated for agreement with collection totals. Finally filed in paid card files the cards themselves constitute a history of the customer's account for the months which they cover, showing all required information with respect to charges and also information on their faces as to the date on which they were paid.

A trial balance of customers' accounts is readily obtained by tabulation of the unpaid cards, either all at one time or by cycle balance.

From our experience of more than fifteen years with this method of keeping customers' accounts, we would venture the opinion that this method of accounting is most practicable in a utility whose number of accounts is sufficient to utilize the capacity of at least one set of machines. However, the method is not economically denied to smaller utilities since the capacity not immediately required for consumers' accounts can well be devoted to tabulation work in connection with labor or material distributions, or other general office work.

This method uses a maximum amount of automatic mechanical equipment and a minimum amount of clerical help. The system is tight from the standpoint of proper accounting. It renders less burdensome the preparation of all necessary statistics. No difficulties are encountered in maintaining the balance of detail ledgers with control accounts.

Although cost figures for comparison with other utilities using different methods of customers' accounting are not available to us, we believe the scheme is at least as economical as any other method of keeping customers' accounts, and in addition, has a considerable advantage in the matter of convenience of administration.

If any of the members of this Association are interested in the details of the methods here referred to, we will be pleased to furnish them with a write-up we have prepared, giving a complete outline of the method of handling the billing against our customers which at this date involves 129,000 accounts billed each month.

ACCOUNTS NECESSARY FOR MECHANICAL BILLING EQUIPMENT

By W. P. Adams[1]

During the past decade the subject of the application of mechanical equipment in the various phases of utility accounting work has been under discussion at nearly all accounting section meetings of our national utility associations. As the customer accounting job is the largest part of utility accounting work, the greater part of these discussions have centered about the application of machines to customer billing. In recent years the amount of customer accounting work in water utilities has steadily increased due to the rapid replacement of flat rates by metered rates, the adoption of more complex rate structures and the additional number of revenue classifications. In many cases also the number of billing periods per year has been multiplied.

The larger water utilities found that considerable saving in clerical personnel could be effected by adopting billing machines and accounting methods made possible by the use of such machines even in the early stages of the development of customer accounting equipment. As the machine manufacturers improved the quality of their product and developed new features which both increased production per bill clerk and furnished additional accounting information as a by-product the number of water companies using machine methods rapidly increased. Today we find that the majority of water utilities, both municipally and privately owned are utilizing billing machines to print the bill and post the ledger record or to print the bill only.

In previous discussions among water utility accountants, the principal question seems to have been whether or not the application of machines and machine methods to the billing work would effect a saving in the cost of clerical labor. Although some stress has been laid on the improved product in a great majority of cases the economic factor seems to have been paramount. The title of this paper might be interpreted to mean that we will attempt to show that a certain

[1] Public Utility Division, Burroughs Adding Machine Company, Detroit, Mich.

minimum number of accounts is necessary to justify the application of machines and machine methods on the basis of economic savings. However, we believe that there are other factors which should be considered of equal importance, in determining the answer to this question.

The matter of public relations has become more and more important in the eyes of utility executives during the past few years. This applies equally well to municipally or to privately owned utilities. The question of "How can we improve our public relations?" certainly has become one of the chief subjects of discussion among the officials and employees of water utilities. This question might also be asked in a different way, "How can we improve our contact with our customers?"

If an examination is made into this last thought, what is the principal contact with the customer? Of course, the only continuous personal contact the utility has with its customers is through the meter readers, if there are metered customers. Utility officials have been well aware of this fact and have tried to improve the quality of meter reading personnel as well as the methods used in reading. However, the most constant and reliable contact the water company has with its customers is through the water bill. This fact has become more and more recognized during the past few years and the bill is not merely considered as a statement informing the customer of what he owes the company, but is looked upon as a periodic contact with each and every customer. Considering it in this light, the bill may either help to make good public relations or become a possible source of public grievance towards the utility.

Bills which are neat, accurate, distinctive and clear help to produce goodwill and offset to some degree the antagonistic feeling which any communication requiring a cash expenditure naturally produces in most people. Just as the general appearance, size, space for information, etc., has caused many water utilities to swing away from the postcard and adopt the paper form of bill, many companies have made the question of neatness, accuracy and legibility the ruling factor in adopting machines to do the billing rather than basing their judgment on cost of labor and material alone. This has been especially true in the case of small companies and we find companies ranging from 200 to 2000 meters or bills changing from hand to machine methods.

All information which might reasonably be of interest to the cus-

tomer should be shown on the bill. This fact is recognized by nearly all water utilities and usually as much of this information as possible is printed upon the bill by the printer. If it is desirable that part of the information be handled by the printer, the remainder certainly should be printed upon the bill by some type of mechanical equipment if the general effect of the bill is to be pleasing. The portion of the information most generally printed on all bills is the name and address of the utility, location of collection offices and such other general information as may be desired.

Nearly all utilities print the name and address of the customer, together with an account number or other account identification, by means of some form of addressing equipment. The cost of such equipment is usually very low. The use of such equipment is most advantageous, since uniformity of name, address, account number, etc. is obtained once a stencil or plate is prepared. The other factors usually shown on the bill are the date of the bill, the date of the expiration of the discount, the date of the present and previous meter readings, total consumption, the consumption at each rate, gross bill, net bill, unpaid balance and the grand total. This information may be entered upon the bill by hand, typewriter or by billing machines. Hand written bills are seldom neat in appearance and the writing is sometimes done so hurriedly that the figures are not legible. Printed figures are certainly neater and more desirable and although this effect could be obtained by using a typewriter, a billing machine which both prints and accumulates different factors for means of proving the accuracy of the work, is always more economical than the use of a typewriter in typing the bills and then proving the accuracy of the entries at a separate operation.

The entries made on the customer's bill which should be proved for accuracy are the meter readings, the consumption, the break down of the consumption, if any, the gross amount of the bill, the amount of the discount, the net, unpaid balances and the grand total. In addition, there may be other entries such as service charges and special debits which should also be proved. The larger types of billing machines furnish as a by-product, accumulations which enable the Accounting Department to prove the accuracy of the entries very quickly and easily. Although on some of the smaller types of machines, which might be used on a small number of accounts, all these factors may not be proved as quickly, proof is nevertheless effected much more efficiently and easily than if billing machines were not used.

Considered from an accounting standpoint, the accuracy of the computations of both the amount of water used and the extension of the rate should most certainly be proved regardless of the method used, hand or machine. Because of the great amount of work involved, in actual practice many water companies using hand methods do not secure an absolute proof of the correctness of revenue. Probably nothing is more destructive to the maintenance of good public relations than the rendering of bills which may contain many errors.

If we assume that good accounting practice demands that the customer's bill be made accurately, in making a study of the cost of customer billing in a water utility having a small number of accounts, this factor must be taken into consideration.

Some small water companies may have the idea that mechanical billing equipment will cost them far more than they feel they can afford to invest. However, the mechanical equipment manufacturers have made great improvements in machines adapted for the customer accounting work in small utilities and a wide range of models makes it comparatively easy to select the type of machine suitable to handle the work to be done and at a cost that no water utility can afford to ignore, considering the benefits to be gained, both from the standpoint of accounting and public relations.

Consideration must also be given to the fact that the accounting machine manufacturers have developed machines which will not only handle the customer accounting work in the small utility but will also handle other classes of accounting work, such as payroll, material and supplies, accounts payable, general records and reports. This same type of machine is very popular for municipal accounting as both the water and tax billing may be done by the same clerical force. In addition, assessment records, budgetary accounting, etc., may be handled with the same machine.

COST OF MECHANICAL EQUIPMENT

It may be of interest to give some concrete examples of just what the cost is for mechanical equipment to do this work in the smaller water utility. For this purpose reference is made to some of the different types of machines which one equipment manufacturer has developed for handling customer and other accounting work.

For utilities having from 200 to about 1000 accounts per month, a small type of billing machine has been developed which will produce a very neat and accurate bill at a cost to the utility of about $1.00 per

week for the machine. This cost is based on a seven year amortization of original purchase price, together with interest on the investment and maintenance charges during this period. In addition, when this machine is not being utilized on billing work, it may be used for general figure work of all kinds.

Another type of accounting machine will handle from 200 to about 2000 bills a month at a cost of less than $2.00 per week for the machine. Still another type of machine which not only will handle the billing work on several thousand accounts, but will also do all the general accounting work in a small water utility, or the tax, assessment and budgetary accounting of a municipality, can be obtained at a cost of about $5.00 per week.

The fourth type of machine which would be principally used for customer accounting purposes, will handle efficiently from 2000 to in excess of 20,000 bills per month according to the accounting system system used and the number of customers involved. The cost of this machine would be about $5.00 per week.

When a proper analysis of the work to be done in the office of any specific utility is made, the proper machine for the job can be easily determined.

Considering the very small cost for adequate machine equipment, entirely disregarding the possibility of actual savings being effected, it is apparent that almost any water utility can well afford to utilize modern mechanical equipment and advanced accounting methods on this important work. If the application of billing machines will aid the customer accounting department in decreasing the number of customer's complaints and tend to improve the public relations, most certainly the great majority of water works officials would be justified in spending a few cents per day to achieve these results. Cannot the answer to the question asked in the subject of this paper be properly answered by stating that, regardless of the number of customer accounts, no water utility can afford to ignore the advantages of machine made customer records and bills?

THE PERMANENT METER READING BOOK VERSUS TEMPORARY METER READING SLIPS

By Carl K. Chapin[1]

That very eminent English jurist, Sir William Blackstone is frequently quoted as having said that the "extreme limit of justice was the height of injustice."

In studying for a moment, either extreme method of handling meter readings, that is, by reading slips, later to be transcribed into read books, or the opposite method of entering readings directly into read books, and not using reading slips, it would appear that such extremes fall within the same realm of ridiculousness that Blackstone expressed in regard to justice without reason.

The best service to the public, when tempered with economic reasons of management, will find *joint use of read books used in the field* for regular periodic reading, and reading slips *used in the field* for all miscellaneous readings, for "on" and "off" orders, memo reads and countless other instances.

This is not to be considered as an attempt to avoid the issue of saying which is considered the better practice as an exclusive method, but it is an attempt to show how both methods may be reconciled in good practice to render very efficient and prompt service.

If we carefully note the changes in meter reading accounting during the last twenty-five years, we will come face to face with two definite changes in this branch of our utility work. Meter reading has changed from a minor to a major position, along with the rapid change from flat rate to metered practices; and it now occupies a prominent position due to the practical elimination of flat rate service in cities, large and small, with few exceptions, notably, Chicago.

Meter reading by books or read slips was formerly considered as incidental to the building of a consumers' account ledger. But, however, we find a second definite change. Consumers' ledgers have shown marked tendency to pull away from the old practice of con-

[1] Commercial Director, Department of Water and Power, Los Angeles, Calif.

tinuous ledger record of service from twelve to twenty-four or even thirty-six months, and we find in their place, largely because of the development of mechanical accounting machines, the turn toward a consumers' account record, which is active only until paid, and then subject to filing in a more or less removed place.

This definite drift toward a card ledger system brings a newer and stronger appeal to depend upon read books for long-time reference to consumers' service records. All of the happenings to which a consumer's service may fall heir can be recorded as an original record in a well-ordered read book. As a record of service, as a medium of complaint investigation, or as a guide to accounting and adjustment, it is without an equal for ready reference and proof of facts. Perhaps that is one of the reasons why of late years, we find the Courts and Federal Income Tax hearings relying upon meter book records rather than consumers' bills or ledger sheets.

Meter books may readily carry two years' record of readings on a particular service. They are easily filed when superseded, and while active, meter books lend themselves well to physical handling for fast progressive billing and consumers' accounting purposes. In the development of serial or cycle reading and billing, book units move easily through the different stages of reading, checking, billing, proving, etc., without introducing inherently objectionable complications or conditions.

For those who wish to prevent a fire loss from wiping out consumer's records, it is necessary to keep only the cosumers' ledger records sufficiently removed from meter book channels, and a fire catastrophe may always be minimized if not completely averted.

Before we commit ourselves further to the admitted importance of meter books and their handling, suppose we examine the present use and importance of reading slips. Regular periodic reading of meters by no means covers all the reading transactions that a metered service may fall heir to. These extra readings are the result of special orders to read certain meters only, for sundry specified reasons, such as a regular "on" order where an idle service now may have a user, or the opposite—an "off" order to read and render a closing bill. These orders may be given in person by the consumer to a counter clerk, and the counter clerk to a field service employee; or the exact opposite—the consumer may give the initial request by 'phone and the counter clerk may transmit order to field entirely by 'phone.

It begins to be apparent that reading slips or their equivalent must

be relied upon to conduct this class of consumers' service promptly. In addition to the simple cases just given, either of the above orders may have developed into an additional order for another consumer and for separate accounting of such service to be billed, in which case, additional meter slips or their equivalent must be made and progressed. If the field service man should find a new user in the premises to be shown as "off" for a previous consumer, he must open the account for the successor.

When new installations are made or upon subsequent abandonment it follows that some form of reading slip or order must progress through the consumers' accounts and regular reading books. Then, too, we have miscellaneous uses for individual readings, occasioned by locked premises or covered meters, where physical changes not anticipated, have prevented a regular reading taking place at its most opportune time.

All of these extra conditions imposed upon the reading of meters, tend toward the opinion that in any well-regulated utility, we are forced to conclude that reading slips or their equivalent must progress expeditiously through the reading and billing system in large quantity.

In cities where consumers' name-changes take place frequently, it is imperative that efficient consumers' accounting requires great elasticity in service record work. It brings us to another conclusion at this point that management responsibility, in providing for the most direct methods to be followed, together with personnel responsibility in the execution of orders and the transcriptions of their meaning, are equally important.

Today the writer received a utility bill which comes to hand sixteen days after the date of meter reading, as printed on the bill, while upon the face of this bill is shown a payment period of fifteen days more time without becoming delinquent. This slowness in rendering statements of service is, to my mind, an improvident granting of credit, wasteful of utility management, and the ultimate burden surely falls upon the consumer. At least ten days or one third of this total period of thirty-one days can be cut out by any consistently applied up-to-date method of consumers' accounting, although some methods lend themselves more readily to efficient operations than do others.

The writer's final conclusion on this question of meter reading slips versus direct posting of readings to read book in the field is this: if a high appreciation of the value of meter readers, as a carefully

selected and well-trained group of employees, is accepted as fundamental in utility management, it is rather easy to arrive at the conclusion that this is not a choice between two extremes in practice, but a problem in receiving the greatest good from a *composite use* of both methods, the prime object being to handle efficiently and accurately the business relations between the consumer and the utility. Our goal of maximum results at minimum costs is always elusive, because of the advance of the art, and perhaps a somewhat changing social structure in community life. Its very elusiveness serves to stimulate us to improve upon past results, and will doubtless serve our successors to the end that they will far oustrip the best results of our time.

PRINTED FORMS AND THEIR CONTROL

By H. J. Johnson[1]

Management cannot function efficiently without complete and adequate records to guide and influence decisions. Many executives have until recently considered records and books necessary evils rather than indispensable aids in the conduct of business. It has been my observation that there is usually a reason for every condition. The reason for records having been in ill repute is that they have failed to accomplish what was expected of them. They have failed to sound the warnings of danger when trouble really existed. They have failed to provide the controls so necessary and vital in guiding those responsible for both the success and failure of every enterprise.

CAUSES FOR SYSTEM FAILURES

Let us consider in what respect record systems have failed. I have in many instances found the same information with slight variations duplicated on as many as three, four or five different forms, whereas one form properly designed would have made it possible to bring the complete information together in one place and would have effected a large saving in clerical effort, filing space, and reference time. The multiplicity of forms that exist today is due to the fact that each time a slight variation in requirements has developed a new form has been added to the collection instead of re-designing the original one. It has resulted in the necessity of duplicating much of the information on each form. Many organizations have reduced the number of forms to less than 25 percent of the original number by proper co-ordination and re-designing.

ELIMINATION OF WASTE

It is impossible even to estimate the tremendous waste caused by recording and keeping data classed as "useless information." The

[1] Public Utility Service Department, Remington-Rand Business Service, Inc., Buffalo, N. Y.

usual reason given for the existence of certain records and reports is "We have always done it that way." If we are to progress we must be willing to junk old pet ideas and methods and try something new. President Hoover recently described the junking of old equipment and methods as "Constructive Waste" and Mr. Insul has declared that the progress of any organization can be measured by the size of its junk pile.

PROPER FILING

It is difficult to imagine any condition more aggravating than not being able to locate the necessary records and information when wanted. Yet, it probably happens oftener than any other one thing. Lost and mis-filed records are nearly always the result of inadequate consideration and thought given to the housing, filing and indexing. The expression "I can't remember what subject I filed it under," is a very common one. This is usually due to the fact that the whole burden of responsibility for deciding on filing subjects and determining where certain material should be filed, is placed on the filing clerk. It is just as important to develop a chart of subjects for filing as to have a chart of accounts for the general ledger.

Perhaps the most serious charge of all is that most of the records in use today have been designed entirely from the departmental viewpoint, rather than from the viewpoint of what is best for the organization as a whole. It is usually the desire of every department to feel entirely independent of every other department. It is unfortunate that this attitude exists, because every individual who is guilty of it is cheating himself out of the opportunity of becoming familiar with the operation of his organization from every angle. We must be able to overlook departmental lines and consider every problem from the standpoint of the entire company's welfare. I am convinced that one of the greatest evils existing in American business today is jealousy among departments and individuals, because it causes each department to disregard the welfare of every other in order that they may be entirely independent of everyone else.

DESIGNING FORMS

The most essential factors in designing a form or record to insure the best possible results are, in my opinion vision, imagination, complete knowledge of the problem involved and an open mind. Just as the architect designing a building, the engineer designing a bridge,

the artist painting a picture or the author writing a book, must have a complete mental picture of the completed work, so must a person designing a form or record have a mental picture of the old system torn down and the new system designed, installed and working. This requires a very thorough knowledge of every requirement and an open mind. It means the subordination of all personal likes, dislikes and prejudices to the welfare of all concerned.

It has been said that the function of a good record system is the furnishing of information recorded thereon when it is wanted. I believe that it should go much farther than this. The system should be so designed and the records so filed that the information recorded is revealed when it is needed without a laborious search and hunt for it.

STANDARDIZATION OF FORMS

Just what may be accomplished by standardizing and properly controlling the printed forms and the necessary organization for handling them? As a conservative estimate the number of forms in the average organization can be reduced at least 35 percent. Records prove that the actual reduction in a large number of organizations has been much greater than this. I will, however, mention only two or three.

One prominent gas and electric company recently made an analysis of the consumers bill forms in their various properties and found that they had 143 designs which were reduced to 36. There were 78 different sizes which were reduced to two. There were 89 different kinds of papers which were reduced to two. There were nine different colors which were reduced to two. The annual cost of the old forms was $22,531.00. This cost after the standardization was reduced to $9068.00, a saving of 60 percent or $13,463.00 per year. The same organization discovered that they had 104 stock forms in 35 different sizes, 7 different colors and 10 different grades of paper, which were reduced to one.

We recently made an analysis of the card files of an organization and found that they had 235 different sizes, colors, kinds and grades of paper which were reduced to about 10 or 12. Perhaps these cases all seem to be a bit extreme, but as a matter of fact they are typical of hundreds that have come to our attention. The reasons for these conditions are that when a form is needed, it is originated in the department, drawn up by some clerk or possibly the department head,

a printer is called in and asked to submit prices and paper samples. The person who is making the decision feels of the paper and decides on one that seems to be about the kind and grade that he had in mind and places the order. No thought is given to the actual requirements of the record, the method of filing, indexing and the kind of usage that the forms will receive.

The average requisition for reprinting forms specifies "same as last." The purchasing order is made out to the lowest bidder who found a cheaper paper and the forms come in showing a saving in the cost of the paper, but the potential loss in efficient service is sustained every time this form is used. Modern efficiency standards demand that each form, ledger sheet and card index be analyzed to determine its service requirements and the exact paper specifications worked out.

SYSTEMS AND PLANNING DEPARTMENT

We are now confronted with the problem of how existing conditions can be corrected and a repetition of them avoided. In a moderate size organization the responsibility for proper standardization and approval of forms may be assigned to one of the executives. In a larger organization it is usually advisable to set up a committee or a department known as the Systems and Planning Department. In order to start the activities of such a Committee or Department properly a complete survey and analysis should be made of the existing forms by someone thoroughly experienced in the work, who will make recommendations to this Committee covering all necessary changes, set up standard printing specifications covering each individual form, as well as procedure and specifications to be followed by the Committee in approving new forms submitted to them.

AUTHORIZING NEW FORMS

The department originating a form should prepare a formal application to the Systems and Planning Department for their approval. The following questions should be answered on the application:

What is the form to be used for?

Is it temporary, semi-permanent or permanent?

Will the usage be mild, normal, rough or abusive?

This information will make it possible to determine the grade and weight of paper to be used. Forms to be used one year or less are classed as temporary. Forms used from one to five years are classed

as semi-permanent and forms that will remain in service indefinitely are classed as permanent. The kind of treatment which the forms will receive is of utmost importance in determining whether all sulphite, a partial rag content of a 100 percent rag stock should be used.

ANALYZING FORM REQUIREMENTS

If the form is to be hand written, horizontal lines should be provided. If it is to be typewritten no horizontal lines should be provided, but indication marks for insertion and registration in the machine should be used. The form should be spaced 10 to the inch horizontally and 6 to the inch vertically in order to eliminate the necessity of adjusting the form a fraction of a space. Cheaper paper can be used if the form is to be typewritten than if pen and ink are to be used. Special attention should be given to the arrangement of the various spaces so that tabulator stops may be used on the typewriter in order to avoid the necessity of hand setting the carriage.

If the form is to be filed in visible equipment, special attention should be given to the visible margin and space must be provided for transfer filing after it has been removed from the active file. If the form is to be housed in a vertical file special attention should be given to the location of the symbol or heading by which it is indexed, also to the size of guides, folders and filing equipment to be used. If it is to be filed in loose leaf binders, consideration must be given to size of the binding margin and the type of punching to be used.

All types of binders have some advantages and some disadvantages. Post binders are not entirely satisfactory if frequent removals and insertions are to be made in various places in the book. The tong binder is the most satisfactory from a standpoint of flexibility and ease of handling and the absence of projecting posts makes it possible to stack binders of this type and they may be used on desks or counters without injury to the surface. Ring binders should only be used on small size forms and where the activity and reference to the record are very limited.

It is important that the symbol or other designation by which forms are sorted and arranged be placed in a convenient position for this purpose.

The form being replaced should be carefully analyzed to determine that provision has been made on the new form for all necessary information. The old form should then be definitely placed out of service and any existing supply destroyed.

All forms that are filed together should be of uniform size in so far as possible and all information that may be posted to another record should be carefully grouped.

Frequently an excess number of copies are provided whereas by proper planning one copy may be routed to two or more departments. Multiplicity of copies not only increases the cost, but the filing space required. It is also suggested that routing and operating instructions be printed on each individual copy and each copy should be made distinctive either by the color of the paper, the color of the ink or in some other effective manner.

Nearly all forms can be reduced in size and effect savings in cost of forms, filing space and handling. Special attention should be given to having all forms printed in standard sizes in order to fit binders, filing cabinets, guides and folders of standard size and cut out of standard size paper stock. The average printing bill can be reduced 10 percent by special attention being given to this very important factor.

If the form originates in more than one department special attention should be given to the elimination of unnecessary rewriting and transcribing and departments so affected should be consulted in order to determine that their requirements have been fully met in every respect.

Every department to which any copy of the form is routed should be consulted to determine that all information required is provided and in the most convenient manner for their purpose. If certain information which is of no interest to various departments is likely to be confusing, special blocking out designs should be used in order that the desired information may be made more prominent. All related information should be carefully grouped.

Requirements should be carefully determined. A tremendous waste occurs in the average organization through the ordering of a larger quantity than is needed. Sometimes the revision of a form is delayed for a long period of time in order to permit the existing supply of forms to become exhausted.

The relation of clerical labor cost to the cost of office forms, supplies and equipment is 30 to 1. That is, for every dollar spent for office equipment and supplies $30.00 is spent for supervisory and clerical salaries. This fact emphasizes in no uncertain terms the extreme importance of designing and selecting the forms and equipment that will provide the greatest possible efficiency and consequently effect reduction in clerical labor cost.

MACHINE BILLING IN STRATFORD, ONTARIO

By A. B. Manson[1]

This subject as indicated by the Program is to be discussed from the Canadian point of view. Just wherein it may differ from the view point of the utility management in the United States is not clear and perhaps is not vital to the present discussion. However, we are pleased to know that the American Water Works Association has seen fit to organize this division known as the Finance and Accounting Division as it must be patent to many that management within the office is the unseen force which drives all that is physical within the utility and is one of the most important factors of this present commercial age. Machinery and materials may be put to work and workers may labour, but without adequate management to organize and consolidate them into a coördinated entity, to distribute the results effectively and to govern performance economically, the results will be disappointing. Although we are in the midst of a period of transition where various factors in our industrial life seem to be aligned against one another, nevertheless executives have come to talk management and the general public is realizing that in the force of management lies the path to a better understanding of our problems. The goal of all enterprises is the same—profits in the greatest amount whether it be in money or service, to the owners of the business, which in this case is largely the public. Business is organized for profit and management methods that do not take this into account, have proved of little value. Into this general field of management is interjected the detail of office equipment, one branch of which is the rendering of bills or accounts for service rendered which detail it is proposed to discuss.

In a large number of our Canadian cities as indicated by Mr. Bond several utilities are controlled by one management which simplifies the relationship between the public and the administration and also the administration itself. Particularly is this the case in the Billing Office and many economies are thus effected. The full advantage

[1] General Manager, Public Utility Commission, Stratford, Ont.

of this situation is secured when billing is performed by machine. Probably our remarks may be more intelligent if confined to a local condition and we may be excused if our Stratford Office is taken as the example of a general situation in many Canadian cities. In this office, electric, water and gas departments are administered under a general supervision of the Hydro Electric Power Commission of Ontario. Billing for electric current and water is combined on one bill and that for gas is handled as a separate operation. Prior to the advent of the machine method all bills were computed and written separately either in longhand or by typewriter. This required a considerable staff and errors depended too much on the personal equation for the monotony of bill writing is very real. After inquiry into its possibilities a Burroughs seventeen bank capacity billing machine capable of setting up two commodities on the one bill was purchased. Stratford has a population of about 20,000 and supplies 5,000 customers, each with electrical and water service and about 1,000 with gas service. Billing is carried out on the bi-monthly plan, except in the cases of commercial and power services which are billed monthly. The city is divided into ten districts with five payment dates which provides an even flow of work for meter readers, Billing Department, Cashiers duty and cash posting. Each district or ledger of about 500 accounts is balanced after every due date. By the use of the billing machine the customers bill, cashiers coupon, ledger record, and recapitulation sheet are made by one operation. Water and electric accounts are entered on the one bill, also arrears and merchandise before removal from the machine. The bills previously addressed by an addressing machine, show all the information necessary to enable the customer to check the accuracy of the charges which complete information tends to maintain confidence as between the customers and the utility company. Neatness, legibility and accuracy should received paramount attention in any public service.

Proceeding beyond the mere billing operation the recapitulation sheet gives the office all the information shown on the customers bill which when accumulated is used to prove the accuracy of the billing and to establish the current debit for the control ledger as well as statistical information such as, quantities of water, electricity or gas used, which would otherwise be a very tedious process in computing.

In the accounting department also the billing machine has proved to be of great assistance. After the due date has been passed, accounts outstanding are listed and these with the cash received must

balance with the billing for that particular section. As soon as this balance is taken off notice of arrears is sent to each consumer in arrears. The office feels perfectly safe in assuming that the amount outstanding is the correct balance. When closing the general ledger at the end of the month the accounts receivable are easily determined which could not be obtained formerly without a great deal of work.

The operation of this mechanically complex piece of machinery is not difficult. In a remarkably short time a quite proficient operator was trained in its complete operation while two understudies are always in supply. Speed and accuracy compatible with reasonable labour is always desired and this chief operator regularly writes 60 accounts and checks the recapitulation sheet in 20 minutes, that is 1 account is written and proved every 20 seconds. It is needless to say that very few errors are permissible to maintain this record. By actual count the errors averaged 1 to every 1360 accounts, an almost negligible amount. The operator is comfortably placed before her machine with tables of rates and meter reader slips conveniently exhibited on her left and ledger cards and bills on the right—all so located as to require the minimum amount of movement and lost time. Periods of change or rest are interjected as required. Machines are wonderful pace makers and automatically keep up the necessary flow of work to have the billing done on time.

As previously mentioned water and electrical services are written on the one bill. This eliminates a great deal of duplication both in material and labour with a consequent economy to the Billing Department. The comparison is probably more real when we say that the cost of billing was reduced by machine methods over the longhand or typewriter method by 1.3 cents per accounts.

The "esprit de corps" of the office is better by the elimination of the slow protracted previous methods. This more cheerful office atmosphere is radiated into the work which now has the feeling of drudgery removed. The legibility, neatness and accuracy of the bill inspires a confidence with the public that is most necessary to the successful operation of a utility which depends so much on the good will of its customers.

THE THEME DISCUSSED FROM THE CANADIAN POINT OF VIEW

By R. M. Bond[1]

I do not presume to cover the whole field as outlined above in the few minutes at my disposal or to speak as an authority representative of the whole of the Dominion of Canada, but I shall try to give you some idea as to why the Hydro-Electric Power Commission of Ontario is interested in this division of the Convention.

In the province of Ontario the Hydro-Electric Power Commission supplies power to some 26 cities, 94 towns, and 187 villages, and deals with them as units through their elected Commissioners or officials. Of this number 86 have joint electric and water departments, that is, both departments come under the one Commission and management, and in a number of cases have the same operating staff. This condition obviously brings about an exceedingly close relationship in accounting matters and considerable care has to be exercised in order that the revenues and expenditures may be properly allocated in both departments.

We have found from experience that the revenue very seldom was credited to the wrong department, but on the other hand, we had to give the expenditures very close scrutiny as the consciences of the local officials were not so keen in this respect and it was so very easy to charge the one department with all of the office expense or a considerable portion of the superintendent's time, or the lion's share of the commissioners renumeration. We also found that it was usually the electric department that suffered in this respect as the water rates were, in most cases, set at so low a figure that a deficit was the usual thing and the electric department, in which more common-sense as to rates had been exercised, usually had money in the bank. In any event an error would not quickly be located, as the local auditors were not thoroughly conversant or acquainted with the departmental operations and as long as they were legitimate expenditures of the Public Utilities

[1] Auditor of Municipal Accounts, Hydro-Electric Power Commission of Ontario, Toronto, Ont.

Commission and were authorized properly it did not seem to make much difference which department paid them. We soon concluded that in order to protect the interests of the electric department our auditors had to check all vouchers in both departments and we have gradually found the opportunity to assist the local officials to establish more up-to-date bookkeeping methods in a number of cases as a result.

In the electric department, a standard system of accounting is in operation and we are hopeful of doing something to bring about a similar condition in the water departments where we have jurisdiction and have already standardized on the primary forms, such as journals, ledger, cash-book and meter-reading slips. Such a change, however, will not be brought about generally very quickly as in municipal operations in Ontario it is the usual practice for the municipalities to absorb any profit or loss in the water department and they therefore are not anxious to start anything that may increase their expenses.

Another point of contact is in the billing. It has been found that a combination water and light bill is very acceptable from the consumer's standpoint, and economical from that of the Utility Commission's. The consumer finds that a two months' bill is easier to provide for in comparison with a three or six months' bill, and the Commission finds that expenses are cut down in respect to meter reading and other billing expenses, such as postage and stationery, etc.

Machine billing is coming more to the fore each year and several of the joint utilities have placed machines in operation within the last few years. I have procured some data concerning this phase that may be of interest, and Mr. Manson of Stratford will outline an individual operation in more detail later on. Fourteen municipalities operating joint utilities in the district near Toronto have installed billing machines. Of this number seven send out combination bills, nine render bills bimonthly, four render bills quarterly, five use flat rates, and four have all customers on meters.

I assume that the municipalities that are progressive enough to install billing machines are representative of the more up-to-date operations and it is quite apparent that of the others a considerable number remain in which more or less antiquated methods prevail and in which a diversity of accounting practices are in operation. To illustrate further, I have found on investigation that some water departments accumulate their operating surpluses and use them as far as possible in financing extensions, others turn over all profits to the Municipal Treasurer, who in turn finances all extensions and renewals until

such time as the aggregate amount is large enough to issue debentures and thus pass the carrying charges on to the utility, and still others accumulate the surpluses and occasionally make grants to the Municipal Treasury to be used in reducing the general tax rate. Also only a very few of the water departments have a definite system of building up a Depreciation Reserve for taking care of obsolescence and most of them do not establish any Renewals Reserve, and the only conclusion that can be arrived at is that a standard system of accounting is badly needed and I feel sure that if this division of the Association can do anything to bring into being such a system they will have more than justified their existence.

I am well aware that there are differences in municipal as against private operation, but most certainly the fundamental principles of sound business should prevail in each case, and a clear cut picture of each type of operation should be recorded in such a manner as to enable an intelligent comparison to be made with identical operations in other Systems. We will not be speaking in the same terms in our discussions, nor can we accomplish a great deal of lasting worth until that time arrives. The argument may be presented that legislation must be obtained to enable us to set about certain things and this may be used as a reason for proceeding as heretofore, but I contend that no legislation or permission is needed to justify good business methods, but rather it is our bounden duty to put into operation a system that will produce authentic and intelligent records.

Being a stranger in your meetings, I may possibly be forgiven if I have plowed in old furrows, and if your Association has any such plan in mind I would be very glad to be informed of it.

THE SILENT PARTNER—THE PUBLIC

By A. P. Michaels[1]

Whether a public utility recognizes it or not, it has public relations, as that is the nature of its business. Inasmuch as the utility occupies such great prominence, it is receiving very close scrutiny, and with the growth of population and the ramifications of the modern social scheme, the means by which any person or group can make themselves heard or known have become more numerous, diverse and relatively difficult. No other line of activity is given the opportunity for service and good will as that of the public utility and it is in the power of the utility to make these public relations good, bad or indifferent, depending upon the kind of a policy which it adopts in giving service and in the treatment of the public.

There are many angles to the subject of proper public relations and many theories as to how to obtain them, but fundamentally, there is not much new on the subject which has merely became more complicated.

Notwithstanding all that has been said or written during the past few years on the subject, there undoubtedly lurks in the minds of a considerable portion of the public an opinion of public utilities which is not flattering. Executives must assume, therefore, a definitely aggressive attitude toward a remedy to overcome that opinion and create a more favorable opinion.

The days have long since passed when the management of a water company or public utility, be it privately or publicly owned, can ignore the public or public opinion. When public utilities men discuss problems or compare results, it is not very long before the subject of public relations, which should be constantly on the minds of the executives, will come up for discussion and keen interest always results.

Our consumers and the public are our partners, so to speak, in the public utility business, and can either make or break the company or the operating executives, so that the company or executives

[1] General Manager, Orlando Utilities Commission, Orlando, Fla.

are only as strong as their public relations. A utility may have excellent equipment, capable engineers, and good technical management and yet lack the most important element for continued success, namely: the good will of the public.

Public good will should be much desired, and its capture or holding is no hit or miss proposition, and experience has demonstrated that it cannot be secured by treating with consumers as classes or communities, but rather by giving recognition to the individuality of each whose friendship or understanding is desired.

The first impressions are generally the lasting ones and every effort should be made to have these pleasing and satisfactory to the customer, so it behooves the utility to have the personnel of this contacting point very carefully chosen. Experience indicates that men with an efficient, courteous, friendly manner, with an understanding of human nature, with a sympathetic ear, and with a desire to please the customers, fill the position best.

These men should possess natural judgment, a good education and training, have a good personal appearance, and the ability to take a certain amount of abuse without becoming exasperated, even when circumstances are trying.

It will be found that there is a charm and satisfaction attached to doing business with a utility which gives good dependable service at the lowest possible cost and has a sympathetic consideration for its employees and customers, and this reaction is found in a warm and enduring friendship.

The Orlando Utilities Commission has experimented with various types of men to fill this all important position and has settled upon the salesman type, preferably one with road experience, as it has been their training to keep the customer satisfied. The other type of men has proven unsatisfactory, as their method of approach is one that in a great many instances irritates instead of pleases the customer. One thing that has worked to produce confidence is that no employee of the Orlando Utilities Commission is permitted to break faith with the consumer, for the instructions are to carry out the promises made to the customer. Even if an ill advised or rash promise is made, this should be carried out so that the customer who is an innocent party in the proceedings will not be made a party to the controversy or misunderstanding. These are matters which can be straightened out behind the doors and are within the family.

The broader concept of good public relations runs the entire scale

of public utility activity, taking in such factors as might be classed as tangible, such as physical parts of plants, and operation of the pumping plant. Such factors are:

The quality and reliability of the source of supply.
The adequacy or inadequacy of the distribution system.
The quality and continuity of service.
The accuracy of the meters.
The efficiency of the meter readers.
The testing of meters.
The proper billing of accounts.
Rate schedules.
The construction and maintenance policies and the promptness with which they are attended to.
The qualities of the finished water, such as:
- Potability, purity and wholesomeness.
- Freedom from pollution, contamination, and poisonous or objectionable salts.
- Freedom from tastes, odors, etc.
- Freedom from corrosiveness.
- Hardness of water, etc.

Among the intangible or personal factors the following appear:

The personal contact of officers and employees
The handling of consumers' inquiries
The handling of consumers' complaints
The policy of adjustments and allowances
Credit and collection policies
Non-pay disconnects
Furnishing of information and publicity
Advertising, etc.

There are proponents for both sides of the question as to whether the physical outweigh the non-physical or personal features of good public relations, or vice-versa. From experience, and at the risk of the resulting criticism which comes from taking a stand on any controversial question, the writer is of the opinion that the non-physical far outweighs the physical features, for good service, efficient operation, and reasonable charges are not sufficient. It does not matter how much capital the utility may have, how fair its rates may be, or how favorable the conditions of service may be, the utility will eventually fail if it does not have a sympathetic public behind it. The public pays for these features and has a right to expect them, and on top of this basic foundation, for a successful

public utility there must be erected a mechanism to get and maintain good relations.

There are three principal ways by which the public reaches its conclusions about a utility company, and these may be termed the "points of contact." The first is letter writing, the second the telephone, and the third the personal contact.

All three are important. All points of contact must be carefully protected, otherwise the object to be attained will be postponed or entirely defeated. If two of these points of contact in a utility company's organization are fulfilling their functions and the other is not, then the harm being done in one direction is probably counteracting the good work done in other ways.

The writing of letters is of vital importance; many complaints are forwarded in letters; many inquiries are received and requests made through the mail. If the customer who writes a letter has some grievance, real or imaginary, he should be conciliated by receiving a reply with full information, if possible, regarding all the circumstances surrounding the alleged cause of complaint. It is bad policy, even if the facts seem to justify, to so word a letter that it will humiliate a consumer because he has made an erroneous statement or an unwarranted charge. There is nothing gained by such methods.

Some people have an idea that every public utility company should supply service upon demand. Whenever possible such people should be talked to personally by an employee with tactful tongue and patient disposition. But if a letter is sent informing the writer that service must be refused, then it should contain a careful and considerate explanation of all facts. Such a letter should have the personal touch, avoiding any resemblance to a communication which might be considered general in its character, and should contain very few technical expressions. Most people are not familiar with the technical terms used in a utility. What the customer wants is water service, not explanations.

The telephone, the second point of contact, bids fair to become one day the most important of all in so far as number of consumers handled is concerned. It is not difficult to realize how essential it is to keep this line of contact well oiled and well attended. It should be remembered that there are always three parties to a telephone call, the person calling, the telephone company, and the person called. That one or two of these parties do their work properly is not sufficient. It may be assumed that the telephone company

does its part perfectly, that its service is sufficient. Therefore, we will consider only the person calling and the person called. In telephone usage, the tone and manner of speech, and the choice of words has everything to do with the feeling created. Half the art of good telephoning lies in deliberate talking. The impression made is entirely by what one says and the way one says it. In answering telephone calls, the operator should use the company's name, the name of the department, or the telephone number as best fits the situation. An employee is never so busy that he cannot furnish the public with proper information, and should do so courteously even over the telephone.

The last but by no means the least important of these is personal contact and the spoken word. In making this statement one should not be unmindful of operations as a whole and should there be anything lacking in this respect the true conditions should be known and through personal contact and proper explanation a better feeling would be manifested by the public. In any case a sense of relative value is essential to success in any modern activity.

There is no greater asset a utility can possess than the confidence of its customers and the good will of the general public, and there is no means whereby a utility is measured or judged more constantly or more accurately than by the "spoken word" as used by the utility's officers and employees. This is neither an old adage nor a new theory, but a fact.

When a man belongs to an organization it goes without saying he will be loyal to its interests. If he cannot be, he should sever his connections immediately or lose the respect of his fellow-men.

The points of personal contact in the central station company's organization are numerous and important. In the office there are many clerks, and on the outside—calling upon consumers at their places of business, or in their homes, are salesmen, collectors, meter-readers, trouble-men and inspectors. And this is not all, for at times there are also construction and service men. The work of these men is varied, but in some respects they should all act in the same way. Each should understand his own duties, and leave a good impression on the consumer after he has finished his particular business, so that the next man coming along and representing the same company, may find the consumer in a friendly frame of mind, because of the good treatment received at the hands of employees who preceded. Where all employees should be alike is in seeing that

the consumer receives the considerate, careful, attentive and courteous treatment to which he is entitled. As for the service man, and construction boss, when these men are careful of the trees, shrubs, flowers and lawns when doing their work, and clean up the mess they usually make before they leave, they will receive commendation that will reach the ears of the company. These conditions may be ideal, but they are not impossible. They may be termed visionary, but in reality they have been known to occur. Politeness and courtesy are like air cushions—there may be nothing to it, but it eases the jolts wonderfully. Consideration for and attention to the other fellow's requests may take a little effort, but if regularly practiced they will earn immense returns.

A voice with a smile over the telephone, a pleasant, intelligent face at the cashier window, a prompt and efficient reply to a service call will do more to better public relations than a full page newspaper advertisement.

Public relations are made up to a great extent by individual contacts, and much can be made of such contacts to promote the correct type of knowledge and to convince the customer of sincerity, reasonableness, and square dealing. However, this must be backed by the proper policy or policies of the company, so that we should feel that to serve a community is both an opportunity and an obligation and we should maintain that no one is properly served unless there exists that fine and intimate relationship inspired by mutual confidence. The chief policy should be to give the greatest amount of water consistent with good dependable service for the lowest possible cost. We should have an unwritten agreement with every customer and the public that they may call on us at any time for information, advice, or counsel, concerning our service or our product.

Successful business is business plus personality. The more personality that is crowded into business the faster it will grow and prosper. Many capable officials used to believe that their success in the public utility field was assured by the mere knowledge of the details of his job plus hard work. This narrowed view has kept many from achieving their real possibilities.

Each employee from the president down to the office boy must be "public relation" minded and must be sufficiently informed about the business to the extent necessary to discuss it in every day encounters. It is essential that the ideas regarding good public relations should penetrate the entire organization as there have been occasions where

the executives had the right ideas, but did not make it a point to see that these ideas were developed among their associates and employees down the line. Consequently, these good intentions and excellent thoughts were dissipated and lost.

The officials and employees of a public utility organization which enjoys good public relations and favor will tend to absorb therefrom a pride in the institution and an enthusiasm which will stimulate them to a high standard of effort in maintaining its good will.

An employee takes on some of the glory or bears some of the stigma, as the case may be, of the organization in which his energies are expended. This thought should stimulate us to analyze and study our service so that we can increase the efficiency of our service department, public contact department, telephone operator, cashier, repair men, meter men, etc., for it is by them that the public utility companies are judged. We are either popular or unpopular to the extent that they serve or neglect to serve the public.

It might not be amiss to state that, from the point of view of the customers, the condition and appearance of the offices are important to the company. If the offices are clean, well lighted, well ventilated, well painted, orderly and equipped with up-to-date equipment, this certainly cannot help but make a favorable impression on the customer. On the other hand, if the employee who comes in contact with the public is unkempt looking, if he needs a shave, if his collar or linen is soiled, his clothes spotted, his shoes unbrushed, he certainly cannot make a good impression on the customer, and yet to that customer that employee represents the company.

There is a great deal of truth in the statement that one unwise move on the part of an employee can do more towards upsetting a utility business routine than the breaking of a part of the physical system, for this can be overcome by having repair parts handy on the shelf, but the same cannot be said about the sudden replacement of an uncoördinated part of the human mechanism.

The policy of the Orlando Utilities Commission and the test of any individual or employee in properly handling the public relations is, when a customer comes in to register a complaint or to present a criticism the definite instructions are never to combat the customer and try to stamp out the complaint, but, if necessary, to develop it so that it can be examined and weighed to find out whether the difficulty is imaginary or real. The Orlando Utilities Commission also impresses upon the employees that it is fully as important to be a

good listener as a good talker and always to guard against the danger of getting so preoccupied in presenting the company's viewpoint that the customer may become irritated and all the work of making him a friend is undone. It means that the public contact man has to be wide awake at all times, because each customer, while he presents a similar problem, surrounds it with a different presentation, as fashion, standards, customs, prejudices, etc. are continually changing and the successful employee must be familiar with the changed conditions.

The public contact employee must understand that it is his function to please the public and to present the customer's viewpoint. Our public contact men are given definite instructions that, if the customer's complaint has merit, then hang on with tenacity until their point is gained, or they will be replaced if they do not. There are quite a few of the employees of the Company who are capable of looking after the company's side, and in order that the consumer may obtain justice and fair dealing it is necessary to have someone look out for his interest.

In handling the public it must be assumed that, if they take the time to come in the office or write about a condition, they may be wrong, but they are certainly sincere and entitled to a sympathetic audience. If the company is at fault, no time should be wasted or stone left unturned to get this untenable situation straightened out, and if the consumer is in error, to use all of the tact and diplomacy to set forth politely the policies of the company.

The unreasoning and unreasonable customer is fast disappearing in territories where good public relations are established. In his place has come the thinking individual marked by fair dealing, who is willing to meet the progressive company more than half way, and whose friendship and good will will become tangible assets.

The employees of the Orlando Utilities Commission are instructed to inquire of each consumer whether or not the service supplied is satisfactory in every respect. This refers not only to the physical service, but also to the consumers relation with meter readers, collectors, trouble-men, clerks, telephone operators, and such other employees of the company with whom they may come in contact.

When a customer with an unpaid balance comes into the credit department and states he owes this balance and cannot pay it and wants to know what we are going to do about it, our answer is "forthwith discontinue the service," but if the customer comes in and tells

us that he owes the balance and cannot pay it all, but will pay a portion and makes definite arrangements for liquidation of the balance, this customer is given every consideration and the collection record will indicate that this policy has not been in error.

The experience of the Orlando Utilities Commission has shown that it is better to keep the records of the company as far removed as possible from the public contact men who handle the complaints; the idea being that, if the employee has not had access to the records, he is less likely to combat the consumer and listen with an attentive and sympathetic ear. After the employee has listened to the entire story of the consumer and they have gotten the trouble off their chest they are in a more approachable mood to listen to frank and courteous explanations of the public contact man who in a moment's time calls up the proper department and gets the company's side of the case. After having heard and seen both sides of the case, it is not a difficult matter to arrive at a fair solution.

Various methods to get these ideas properly to the employees down the line have been experimented with, with varying degrees of success, but it must follow that before the utility can expect good public relations it must hold the good will and interest and loyalty of its own employees. Interest must be shown in their welfare, as it scarcely need be said that the utility should want all of its employees contented, happy, and prosperous, for their own, the utility's, and the public's benefit, as their health of body and mind, their satisfaction with conditions are all reflected in the quality of service rendered to the utility and its consumers.

Some companies have had great success in having a general meeting of its employees once or twice a month at which time inspirational addresses on the subject of public relations would be given. In the experience of the Orlando Utilities Commission, this was not found at all satisfactory and was discarded in favor of the medium of the employee's paper which is published monthly. This paper contains a large amount of personal news about the utility and its employees and families which is interspersed with the messages or the information which the executives are trying to convey, and should be made educational as well as interesting.

A RATING SCALE FOR PUBLIC RELATIONS

By Howard S. Morse[1]

No part of the Water Works Practice Manual, issued by this Association in 1925, is devoted to the subject of Public Relations. However, in the Revision of this Manual now in progress, Committee No. 9 of the Water Works Practice Committee has been assigned the task of producing something worth while with respect to the relations of water utilities to the consumers and public.

The omission of this subject from the first issue of the Manual does not mean that there was little or no interest in the subject of Public Relations back in 1925; but on the other hand I believe it is evident that there has been a growing interest in this subject during the past five years.

This is particularly true with respect to our brother utilities—electric, gas and telephone, but the water utility must share in this interest. The fact that many water utilities are municipally owned, and therefore are not confronted with the issue of municipal ownership and made the marks for newspaper bating, accounts for some lack of emphasis on public relations with respect to water utilities as compared with other utilities. But the municipally owned utility has another and perhaps more immediate interest in public relations in the ever present necessity of keeping partisan or machine politics out of the water business.

There is abundance of literature on the subject of Public Relations between utilities and the consumers. So the Committee did not feel called upon to add its mite to this total and concluded that the best contribution it could make to the Water Works Practice Manual would be to devise a scale by means of which any water utility can be rated with respect to all of the factors bearing on the relations of that utility with its customers.

The rating scale method of analyzing industrial and engineering problems is familiar to all of us. It has long been used by the National Board of Fire Underwriters, it is an essential tool for a

[1] General Manager, Indianapolis Water Company, Indianapolis, Ind.

personnel manager, and it was proposed but laid aside as a part of the Sanitary Survey section of the Treasury Standard of water quality. It needs no defence or apology, but in its application to the public relations problem it does need thoughtful consideration and constructive analysis.

The Rating Scale herewith presented has been developed during the past six months and should be considered as in tentative form, but in reaching this form it has undergone many changes and the participants in this development have found the work both interesting and instructive. One step in development of the Scale was its presentation at the Annual Meeting of the Indiana Section of the American Water Works Association last February, and the purpose in presenting this Scale at this session of the Finance and Accounting Division of the American Water Works Association is to bring out new viewpoints and suggestions for further development of the Scale.

In studying this Scale it should be recognized that its scope and contents must be sufficiently inclusive to cover all water plants large and small, of different types and operating under all varieties of conditions both physical and political. With this fact in mind, this Rating Scale (Table 1) has five major divisions described in general terms by the captions:

1. **Policy and Organization of Utility**
2. **Plant Facilities**
3. **Quality of Supply**
4. **Services to Consumers**
5. **Attitude of Public Toward Public Affairs**

The total of points for a perfect score is placed at 1000, and these 1000 points are distributed between these five major divisions—100 points being allotted to Policy and Organization of Utility, 250 points to Plant Facilities, 250 points to Quality of Supply, 300 points to Services to Consumers, and 100 points to Attitude of Public Toward Public Affairs.

The grading under each of these main divisions and throughout the Scale ranges from Excellent through Good, Fair and Poor. The grading of Very Poor was suggested but in framing the tentative scale has been omitted. Under these different gradings the weights have been apportioned, 80 percent of Excellent being allotted to the grading of Good, 60 percent of Excellent to Fair, and 40 percent to Poor.

TABLE 1

Rating scale—factors contributing to satisfactory public relations of a water utility

	WEIGHT			
	Excellent	Good	Fair	Poor
I. Policy and organization of utility	100	80	60	40
II. Plant facilities	250	200	150	100
III. Quality of supply	250	200	150	100
IV. Services to consumers	300	240	180	120
V. Attitude of public toward public affairs	100	80	60	40
	1,000	800	600	400

TABLE 2

I. Policy and organization of utility

		EXCELLENT	GOOD	FAIR	POOR
30	Policy of municipality or owners toward:				
	Additions to and income from property	10*	8†	6	4
	Public relations	10*	8†	6	4
	Customers ownership of securities	5	4	3*	2†
	Participation in community affairs	5†	4*	3	2
35	Organization				
	Distribution of functions	10	8*	6†	4
	Training of employees	5	4†	3	2
	Adjustment or promotion of employees	5	4†	3	2
	Employee tenure—civil service	10	8†	6	4
	Compensation of personnel	5	4†	3	2
35	Efficiency of personnel:				
	Manager and division heads	20†	16*	12	8
	Skilled employees	10†	8*	6	4
	Unskilled employees	5	4*	3†	2
100		100	80	60	40

* Asterisks and daggers—daggers are outside agencies ratings, asterisks are company staff ratings.

† Daggers only—outside agencies and company staff ratings.

TABLE 3

II. Plant facilities

		EXCEL-LENT	GOOD	FAIR	POOR
25	Adequacy of supply:				
	For present needs	15†	12	9	6
	For future needs	5†	4*	3	2
	Definiteness of forecasts	5†	4	3	2
20	Dependability of all supply works:				
	Fire protection at works	10*	8†	6	4
	Flood protection at works	10	8†	6*	4
30	Source of supply structures:				
	Adequacy of maintenance	5†	4*	3	2
	Adequacy for normal service	15†	12	9	6
	Adequacy for peak service	10†	8*	6	4
30	Boiler plant equipment:				
	Adequacy for normal load	15†	12	9	6
	Adequacy for peak load	10†	8	6	4
	Adequacy of maintenance	5†	4	3	2
30	Pumping equipment:				
	Adequacy for normal load	15†	12	9	6
	Adequacy for peak load	10†	8	6	4
	Adequacy of maintenance	5†	4	3	2
25	Appearance of plant and equipment:				
	Appearance of buildings and grounds	5*	4†	3	2
	Appearance of mechanical equipment	5*	4†	3	2
	Appearance of hydrants	5†	4	3	2
	Appearance of construction and transportation equipment	5†	4	3	2
	Appearance and arrangement of business office	5	4	3†	2
20	Supply mains:				
	Adequacy for peak load	15*	12†	9	6
	Internal condition	5*	4†	3	2
25	Distribution mains, valves, hydrants:				
	Records of system	5†	4	3	2
	Adequacy of valves and hydrants	5	4†	3	2
	Adequacy for normal demand	5*	4†	3	2
	Adequacy for peak	5	4†	3	2
	Adequacy of maintenance-internal condition	5†	4	3	2
30	Service lines and consumers plumbing:				
	Condition of service lines	15	12	9†	6
	Regulation of consumers plumbing	15	12	9†	6
15	Relations of production to sales:				
	Losses in supply works	5	4†	3	2
	Losses in distribution system	5	4†	3	2
	Losses in consumers property	5	4†	3	2
250		250	200	150	100

* Asterisks and daggers—daggers are outside agencies ratings, asterisks are company staff ratings.

† Daggers only—outside agencies and company staff ratings.

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Tables 2 to 6 inclusive show the subdivisions of the five major divisions, with the weights allotted to each at the left of the caption of the subdivision and the weights for the items under the four different grades at the right of each item.

TABLE 4

III. Quality of supply

		EXCELLENT	GOOD	FAIR	POOR
110	Safety:				
	Conformance to recognized standards..	60‡	48	36	24
	Degree of supervision and control.....	40†	32	24	16
	Supervision of connections to private supplies..............................	10	8†	6	4
45	Chemical stability:				
	Conformance to recognized standards..	20	16*	12§	8
	Quality for industrial use.............	5	4*	3†	2
	Quality for domestic use...............	20	16*	12§	8
40	Taste and odor:				
	Normal condition from consumer's viewpoint..................................	30	24†	18	12
	Absence of taste producing materials from raw water.........................	10	8†	6	4
40	Appearance:				
	Normal conformance to recognized standards................................	30	24†	18	12
	Variation due to peak flows............	10	8*	6†	4
15	Temperature:				
	Degree of approach to 50°F............	15	12†	9	6
250		250	200	150	100

* Asterisks and daggers—daggers are outside agencies ratings, asterisks are company staff ratings.

† Daggers only—outside agencies and company staff ratings.

‡ The average of ratings by outside agencies was between "Good" and "Excellent."

§ The average of ratings by outside agencies was between "Fair" and "Good."

The Committee intends to supplement this Rating Scale with a brief description of the subject matter of each item, similar to that attached to an Income Tax Return, though perhaps the municipally owned water utilities are not acquainted with such documents, but, in general, the items throughout this Rating Scale are self explana-

TABLE 5

IV. Service to consumers

		EXCELLENT	GOOD	FAIR	POOR
50	**Rate structure:**				
	Adequacy of total income	15	12†	9	6
	Correctness of allocation among consumers	15	12†	9	6
	Promotional and off-peak rates	5	4*	3	2†
	Degree of control of income and expenditures by utility or department	5*	4†	3	2
	Comparability with other water utilities	10†	8*	6	4
35	**Financing of mains, service lines and meters:**				
	Mains	20†	16	12	8
	Installation, maintenance and replacement of services	10	8†	6	4
	Installation of meters	5†	4	3	2
15	**Construction work in streets:**				
	Protection of excavations	5†	4	3	2
	Efficiency and speed of operations	5†	4	3	2
	Maintenance of pavements	5†	4	3	2
25	**New customers and sales:**				
	Sales promotion policy	5	4*	3†	2
	Office routine	10	8†	6	4
	Connections and disconnections	10*	8†	6	4
15	**Records:**				
	Adequacy	5	4†	3	2
	Correctness	10†	8*	6	4
20	**Meters:**				
	Routine for testing accuracy	5†	4	3	2
	Repair and replacement	15†	12*	9	6
25	**Billing methods:**				
	Meter reading routine	10	8†	6	4
	Accuracy of meter readers	10	8†	6	4
	Office routine—regularity and accuracy	5	4†	3	2
20	**Collection methods:**				
	Credit methods	5	4†	3	2
	Delinquency control	10	8†	6	4
	Adjustment methods	5	4†	3	2
25	**Consumer inquiries:**				
	Records of	5†	4	3	2
	Routine for handling	20†	16*	12	8

† Daggers only—outside agencies and company staff ratings.

* Asterisks and daggers—daggers are outside agencies ratings, asterisks are company staff ratings.

TABLE 5—*Concluded*

		EXCELLENT	GOOD	FAIR	POOR
40	Courtesy of employees to consumers:				
	Management policy	10*	8†	6	4
	Plant employees	5*	4†	3	2
	Service and meter men	10	8†	6	4
	Office employees	15	12*	9†	6
30	Adequacy of public information:				
	Direct to consumer literature	15	12*	9†	6
	Plant inspections	5	4†	3	2
	Newspaper space or advertising	5	4	3*	2†
	Public speaking	5	4	3*	2†
300	Total	300	240	180	120

tory as to what they mean and include. However, there are a few items which may require clarification at this time.

For example, under the first major division "Policy and Organization of Utility" there is the item of "Policy of Municipality or Owners toward Additions to and Income from property." "Additions," of course, refers to physical additions to the plant, and the reference to "Income from property" raises a question as to whether the attitude of the municipality or owners is to squeeze the last dollar from the property and its customers or to be satisfied with a reasonable return and pursue a liberal policy toward the community served by the water utility.

Similarly, the very next item, Policy of Municipality or Owners Toward Public Relations, measures the interest of the owners of municipality in that subject and tests their sensitiveness to poor public relations and the ill will of the community.

At first glance it may appear that these two items cover the same ground. However, a liberal policy in the making of additions and being satisfied with a reasonable income may be nothing more than good business, whereas the attitude of the municipality or owners toward public relations is a better measure of interest in that subject beyond the limits of good business policy.

The last subdivision under the major division of Plant Facilities entitled "Relations of Production to Sales" includes three items of Losses in Supply Works, in Distribution System, and in Consumers' Property. The purpose of these items is to obtain some measure of the efficiency of the plant through the control of Water Losses throughout the system.

TABLE 6

V. Attitude of public toward public affairs

		EXCELLENT	GOOD	FAIR	POOR
25	Attitude of:				
	Public officials toward government and laws	5	4†	3	2
	Newspapers toward government and laws	10	8†	6	4
	Civic clubs toward government and laws	5	4†	3	2
	Citizens toward government and laws	5	4*	3†	2
35	Attitude of:				
	Public officials toward municipal affairs in general	10	8†	6	4
	Newspapers toward municipal affairs in general	15	12†	9	6
	Civic clubs toward municipal affairs in general	5	4*	3†	2
	Citizens toward municipal affairs in general	5	4	3†	2
40	Attitude of:				
	Public officials toward utility organizations	10	8†	6	4
	Newspapers toward utility organizations	15	12	9*	6†
	Civic clubs toward utility organizations	10	8†	6	4
	Citizens toward utility organizations	5	4	3†	2
100	Total	100	80	60	40

	RATING OF INDIANAPOLIS WATER COMPANY	
	By outside agencies	By company staff
Division I	82	83
Division II	220	223
Division III	209	220
Division IV	248	254
Division V	70	75
Total	829	855

* Asterisks and daggers—daggers are outside agencies ratings, asterisks are company staff ratings.

† Daggers only—outside agencies and company staff ratings.

The subdivision of Chemical Stability under the third major division, Quality of Supply, pertains to corrosiveness, hardness and the iron content of the finished product of the plant supplied to the consumers.

Under the fourth major division, Services to Consumers, is one subdivision which may attract some attention. Under the title of "Adequacy of Public Information," are the four items of Direct to Consumer Literature, Plant Inspection, Newspaper Space or Advertising, and Public Speaking. Out of a total of 1000 points for a perfect score of the entire scale, only 30 points are allowed for these four items. The Committee realizes that this small allowance does not conform to a more or less prevalent notion that the way to promote good public relations is through advertising and publicity. However, it is the view of the Committee that this notion is fallacious and that public relations of a water utility can best be secured through a well balanced system covering all of the important factors entering into water works management.

The fifth major division of this Scale, Attitude of Public Toward Public Affairs, is unsatisfactory to the Committee in its present form, but is presented here for what it may be worth in the process of developing the Scale. It represents an attempt to evaluate the local currents or viewpoints outside of the utility organization and plant which bear on its public relations. The outside viewpoints listed are those of Public Officials, Newspapers, Civic Clubs, and Citizens, and it is suggested that the attitudes of these four factors in the civic life toward government and laws in general, but more particularly toward affairs in the community in which the water utility is located and specifically toward other utility organizations in that community, have a very important influence on the attitude of the consumers toward the water utility to which this Rating Scale is being applied.

With the contents, construction, weights and grades of the scale understood, a proper question to raise is the method of application in order to make this scale of practical use to any owner or manager of a water utility. In order to test its value the scale as here presented was submitted to several outside agencies in order to obtain an outside viewpoint of the Indianapolis Water Company with respect to its public relations, and the results of these scorings are shown in tables 2 to 6.

Simultaneously the Rating Scale was submitted by letter and

without explanation to the nine department heads of the Indianapolis Water Company with request that it be applied to that property. Tables 2 to 6 inclusive also show the average scorings of these nine department heads together with that of the Manager. The scorings of the outside agencies and the Staff of the Company are identical in some instances and are so indicated.

The outside agencies which rated the Indianapolis Water Company are the Service and Engineering departments of the Indiana Public Service Commission, the Sanitary Engineer of the State Board of Health, the National Board of Fire Underwriters (1927 Report on Indianapolis Water Company), and the Civic Secretary of the Indianapolis Chamber of Commerce. The particular items rated by each of these agencies are not indicated in the tables but each rated the items on which it was best qualified to pass judgment.

The differences between ratings by the Company Staff and outside agencies are interesting. For example, under "Plant Facilities" the outside agencies think that the Company is better prepared for Future Needs than does the Company itself. Also, they are not as concerned about the lack of Flood Protection as is the Company staff.

The outside rating of the "Quality of Supply" on the whole is not complimentary, especially with respect to Chemical Stability. This difference of opinion is based on hardness and iron content of the water, especially deep well water which is used to a limited extent.

There is little difference between the staff and outside ratings of "Service to Consumers," excepting in Courtesy of Employes, the outside agencies rank the Management Policy and the Office Employes at a lower grade than does the Company staff. Apparently we have excellent intentions, but do not quite hit the mark.

Under the fifth main division which, in effect, is a rating of the Community itself, the outside agencies and the staff are in unusual agreement and wherever there is a difference in rating the outside agencies rate the community lower than does the staff. The opposite would be natural as it could be expected that any utility organization sensitive to its public relations would at times be pessimistic about the attitude of the community either as a whole or in some of its component parts.

Showing of further details of these scorings by department heads would unnecessarily complicate these tables, but it must be evident to any water works manager that the different viewpoints of the

department heads on each of the factors included in this Rating Scale are worth careful consideration and may point the way to improvements, the necessity of which had not before been recognized. Also, while use of this scale in a self survey of a water utility by its own organization can locate weaknesses in plant, organization and methods, and tone up the entire organization in its interest in public relations, the outside viewpoint obtained from use of this scale by outside agencies is even more interesting and stimulating.

"O wad some Power the giftie gie us,
To see oursels as ithers see us!"

And the net result of these efforts to evaluate the performance of plant and organization is certain to be more effective service to the community, which after all is the prime reason for existence of the water utility.

PERSONNEL SERVICE RATING METHODS AND RECORDS

By Joseph F. Majeske[1]

Of all the subjects calling for solution in the personnel field, to me none is more pressing or of greater consequence than the subject of "Service Rating."

Students of personnel administration and personnel officers have worked on the subjects of tests, classifications, compensation plans, and conditions affecting employment; on rules covering hours of work, vacations, sick leaves, promotions, lay-offs, re-employment, and all relating questions; and many and varied are the claims that some or all of these problems have been successfully solved. But have not we neglected quite generally the one operation which is absolutely necessary to prove the success of our work in these personnel problems? Have we not given too little attention to the problem of measuring and determining the service value of the employee that we have so carefully and with such pains inducted into the service. What proof have we that we are recruiting for the service the best personnel to be found in our respective communities, and when it comes time to lay off employees, either for lack of work or of funds, how do we know we are separating the least valuable and retaining in employment the most valuable employee? We all concede that in the interest of the constituency for which we work, be it either public or private corporation, the duty devolves upon us to keep in the service those employees who are the most valuable to the organization.

The question of the value of an employee to his organization includes more than his individual efficiency. We have all seen employees who can read more meters or make out more bills on a billing machine than others, yet have other traits that reduce their value to the employer. For instance, a meter reader who turns in a large number of readings daily may possess a manner and disposition which antagonizes every water consumer that he calls on in the course of his

[1] Director of Personnel, Department of Water Supply, Detroit, Mich.

work, and thus tends to build up a wall of ill will against his company or department; and the employee of a public service corporation who destroys the good will of the public supporting that corporation can be more expensive to his employer than though he were paid his salary and not allowed to do any part of the work.

Likewise, but through another course of conduct, a billing machine operator may be personally very efficient but because of her disposition, she causes dissension among her co-workers, thereby slowing up their work and destroying harmony in the organization. By this she may materially detract from her own value. It is not hard to see that her excess efficiency might be more than absorbed and offset by her disturbing conduct so that as a result, the amount of the individual production, as well as the group production, is actually lower. Pure efficiency ratings do not make this distinction.

I cite the above illustrations to emphasize the point that our great need is a scheme that will rate service value rather than *efficiency* of the employee. Our interest is, after all, in the complete success of our company or department, and not in the individual employee, and yet, by the same token, when we can reliably determine the relative value of a group of employees, then, and then only, can we properly extend recognition and reward. I assume it is safe to say that we have all, at one time or another of our career, been entirely satisfied with the infallibility of our own judgment in the matter of appraising the relative value of employees to our organization. But what proof have we that our own judgment is, in fact, infallible? It is a well known fact, reluctantly recognized and admitted, that human judgment individually exercised is of a very high degree of unreliability. Therefore, the scheme that will approximate mass judgment is the thing to be desired.

We all know that many systems have been evolved and many discarded as impracticable, difficult of execution, and not performing the functions required. In Detroit, through the initiative of the Civil Service Commission, we have installed for a try-out the Probst Service Rating System. We believe this system gives promise of measuring the *value* of employees. In a year from now, we can tell you more definitely of our own experience with it.

It seems to me that we have overlooked a very much worth while study when we have very generally neglected to appreciate properly the personnel of our organizations. It has long since become common practice to prepare elaborate specifications for water pipe, valves,

meters, and so forth. Do we realize that the cost per annum of personnel is no small part of our total cost of maintenance and operation? In my own city, the department which I have the honor to represent is spending this fiscal year for operation and maintenance the sum of $2,300,000.00, of which amount more than $1,000,000.00 is for personal service. This does not take into consideration the amount spent within the construction service, where last year the pay rolls amounted to $4,388,598.00.

Thus it can be clearly seen that there could be a tremendous waste in our personnel. Good business principles demand that we study this question to the end that we may be sure we are getting the most value out of our service. Do we know that our personnel operates smoothly and without friction? We demand this from our mechanical equipment and refuse to be satisfied with anything less. Some people take exception to the claim that an employee is simply a "cog" in a large machine, but, in fact, he is just that, and if he fits in well, functions properly, adds strength and flexibility to the rest of the machine and does not cause friction, he is just as necessary as any other part or person in the organization, but if he does not fit in properly, he is of little or no value. Every individual is the embodiment of certain traits and dispositions. Some traits render a person defective in the performance of certain tasks, others cause him to lack the co-operative spirit or influence. We carefully inspect our mechanical equipment to see that it is up to specifications and has no defects. With our personnel, have we carefully prepared specifications that must be met? Have we made a careful study of traits that are assets and traits that are defects? Can this be done without being influenced by the personal equation, for we all have our own personal prejudices in both "pros" and "cons." We want to know the value to the service of each employee, not just his personal efficiency. Team work is the watch word of success in business to-day, and the larger the organization, the more truth there is in this statement.

I shall not undertake in this paper to go into elaborate detail in explaining the system to which I have referred. I shall simply comment on what appear to be the high spots and the things which will, in a general way, give a picture of what the system undertakes to do, and how it undertakes to do that. In the first instance, this system marks on individual sheets for each employee, and provides for a rating by three superiors, the first rating to be recorded by the

immediate superior, the second by this man's superior, and the third, by the head of the bureau or division. Now, the medium of rating is as follows: On the individual card for each employee is set out some 80 or 100 traits, some of which are usually reflected in and by every individual. Some of these are such as to be very outstanding and have a determined effect on one's disposition, industry, and so forth. These same traits, again, are broken up entirely into minor ones which attribute to the main trait, but every one of which is much less in its general importance. Opposite every one of these characteristics are three blank squares set up in columns, as column 1, 2 and 3. The raters are expected to check the traits, good or bad, that are possessed or reflected by the employee whom they are grading. Necessarily, it will often happen that all three of the raters will not be sufficiently acquainted with the employee to feel qualified to express an opinion on all the characteristics set out, and in cases of this kind it will be up to each one to check only those that he feels he knows, and can conscientiously express an opinion on. For instance, an employee may be "lazy" or if that appears to be a rather too serious charge to make against him, the rater may indicate that he is "slow moving," "too old for the work," or is "indifferent;" he may be a "good team worker," or "one that antagonizes when dealing with others;" and he may "resent criticism," or possess a "cranky disposition." When you come to appreciate that there are nearly 100 traits set out, you can understand that if you are fully advised as to those traits concerning any one individual, you have a good idea of that individual when those traits are set up in a picture.

Of course, it is to be desired and expected that the raters will be entirely honest in their work, and even then, there may be differences of opinion and raters may not agree. It seems to me, however, that it is rather imperative that a general uniformity of judgment should exist in some of the outstanding features. Take, for instance, "turns out an unusual amount of work," "steady worker most of the time," "always busy at work." There does not seem to be much room for difference in judgment as to "always busy at work." "Steady worker most of the time" is also a matter that does not call for any particular judgment. But the trait "turns out an unusually large amount of work" appears to me to call for careful and deliberate consideration, and to demand that all judgments be based as nearly as possible, on the same hypothesis. For instance, what constitutes an unusually large amount of work is a matter upon which judges

may not agree. Do we mean by this to compare the person with the group in which he is working, or do we mean to compare his output with what should be expected of the particular work in hand. It may be possible that there will be such a difference in the judgment of raters on that particular item, and that some general basis should be set up by the head of the department as a measure of work, to be used by all raters, to the end that there will be uniformity in the measuring instrument. A careful study of this system will indicate to the honest inquirer, I think, first, that it possesses possibilities of giving reasonably accurate relative values of a group of employees; second, that it cannot operate automatically, but needs intelligent effort on the part of every person having to do with the fixing of the ratings.

As I have endeavored to point out earlier in this paper, the administration of a personnel cannot be complete and effective without a fairly accurate record of the relative values of the employees. Recognizing this, and knowing that many systems have been tried and found wanting, our department—and I believe our department is not different from others charged with the responsibility of personnel administration—has decided to give this system a fair trial, with a determination to honestly recognize both its merits and its defects, and with the hope of discovering a system to fill the long felt want.

If, and when, this discovery shall have been made and the reliability and validity of the system established, then we can reasonably expect to find this system capable of great assistance in the administration of personnel matters, in that, among other things, it will enable us to proceed intelligently in the recommendation for promotion of the employee who shows the most service value to the organization, or when lay-offs are in order, to lay off those of the least service value, or in considering salary advance, when opportunity offers, to see that such advancement is used as a reward to the most valuable to the service. In fact, it will serve as a basis for the consideration and determination of any question that affects the status of an employee.

As stated above, the City of Detroit is only experimenting with this system as outlined. The need of such system for rating service value is so apparent that every effort should be made to secure a proper measurement of this value.

In conclusion, this paper is presented for the purpose of interesting the industry along lines of thought which will further the ideas of measuring an employee's service in the water works field.

DISCUSSION

C. A. DYKSTRA:[2] One of the chief problems that has always confronted those who have the responsibility for rating employees has been to find a basis of judgment upon which all can agree. One supervisor thinks he is honest n rating an employee in his division at 90 percent; another equally honest thinks he is just in rating the same sort of service at 80 percent. The result is that under ordinary rating systems excellent work may be rated at 80, 85, or 90, as the case may be. Standard work is variously rated from 65 to 80. The personal opinion of the rater when he makes what is called a judgment rating and his personal feeling for a given employee means that there is constant criticism throughout the whole force that there is either prejudice or favoritism operating.

It is somewhat difficult to determine exactly what is standard work, and what is below and what is above. Most rating systems that have been tried in American practice have been unsatisfactory to management and employees alike. This is the reason for attempting in a rating system to get away from merely personal judgments and more or less arbitrary standards. The Probst System attempts an entirely different procedure. It assumes first of all, in most cases, three independent checkings of employee qualities and qualifications, and in the second place a percentile rating of those who do not come into contact with the employee. Several years of testing methods of checking qualities and of giving them proper weights have given us what has come to be called "The Probst Rating System." The Bureau of Public Personnel and The National Civil Service Assembly have given minute and intensive consideration to this system, and have come to the conclusion that it is the best as yet set up.

I have had personal experience with this rating system in two cities. It was my pleasure to give the system the widest trial it had had up to that time in the Water and Power Department in the City of Los Angeles. We took pains to chart the results of our old rating methods alongside the results which we accomplished under the Probst System, checking one against the other. Our mature judgment after a year's experience was, first, that it was more impersonal and subject to less prejudice and favoritism; second, that the rating officers were pleased with its workings; and third, that so far as employees were concerned it was quite apparent that the Probst System ran much

[2] City Manager, Cincinnati, Ohio.

more nearly coincident with the so-called biologic curve. Now if we assume that the biologic curve is justifiable and provable, as our psychologists are insisting, we can conclude that the Probst System is a more accurate measurement of capability. This was our experience in Los Angeles.

In Cincinnati we are now on the second run or ratings under the Probst System. In our first run we discovered that there ran through some departmental supervisors the idea that their own personal subordinates had every known desirable quality and few undesirable ones. It was not difficult, however, to have new ratings made with a little more independence of judgment. Before we sent the second set of forms through we had another meeting with all rating officers in order that they might understand more fully the possibilities of the system. I feel sure that our second experience will bring us much better results.

Our Personnel Office is pleased with the reception of the system by both supervisors and employees. When the first set of reports came in and employees notified of their ratings they were inclined to feel that they had been discriminated against. I do not believe that our second experience will bring this result. They all know that we want to find meritorious service as well as to check up on slovenly work. If a little later we can co-ordinate rewards in the shape of promotions and increases in pay with the efficiency ratings as they are worked out, we can do some sort of justice to everybody. At the present time our budget requests carry columns side by side with space opposite each name on the payroll for a statement of the number of years' service and an efficiency rating. By this means it is possible for the responsible budgetary officer to note exactly what merit there is in a request for salary increase or promotion.

Too often efficiency ratings have been declared highly theoretical and perhaps undependable. Experience with the Probst Rating System indicates that here is a practical rating scheme with a high degree of dependability. In all of our mechanical operations we are placing great importance upon tests and inspections. The human factor involved has had much less attention and much less accurate measurement. From now on we are bound to do as well by the human material which is used in municipal administration as by the mechanical and physical materials which go into our operations.

PURCHASING BY COMPETITIVE BIDDING

By C. J. Alfke[1]

The purpose of this paper is to set forth a simple and effective method covering purchasing by means of securing competitive quotations. Purchasing by means of competitive quotations is most effectively accomplished by centralization of purchasing and the placing of the responsibility of that function of the business under the jurisdiction of one person in order definitely to fix responsibility. Centralization of purchasing usually results in economies. In all of the larger organizations and most of the moderate size organizations purchasing is considered a major function.

Some of the advantages of centralized purchasing are:

(1) Establishing proper control of commitments of the company for materials, equipment and services.

(2) Securing materials, equipment, etc. at the best prices commensurate with quality and service.

(3) Eliminating individual buying in different departments which naturally tends to lax buying, viz: Buying materials or equipment unnecessarily and not at the lowest price commensurate with quality and service.

(4) Maintaining inventories at a minimum.

The procedure in the Purchasing Department must be standardized and the purchasing must be done in accordance with definite policies which are intelligent, honest and impartial.

POLICIES

The more important policies to be followed in the Purchasing Department are:

(1) Award business on the basis of price, quality and service.

(2) Know the amount of each obligation before making a commitment.

(3) Insist upon the personnel of the Department conducting themselves in such a manner as to establish favorable business

[1] Comptroller, Hackensack Water Company, Weethawken, N. J.

relations. A company is judged by the impression its representatives make.

(4) Make clear, concise and complete letters and agreements.

(5) Seek dependability in suppliers, in salesmen and in employees.

CLASSIFICATION OF COMMITMENTS

Depending on the size of the business, purchasing is usually divided into various groups. For a business of a moderate size or one where purchasing can be conducted from one office or plant, the following groups are recommended:

(1) Periodic commitments for materials used in large quantities.

(2) Commitments for materials and/or services of a technical nature.

(3) Commitments for small supplies, etc.

The first group covers materials such as cast iron pipe, cast iron fittings and valves, and chemicals for which a water works company would usually enter into a contract covering the period of one year. It also covers agreements involving services for new construction and/or maintenance work.

The second group, "Commitments for Materials and Supplies of a Technical Nature," includes items of such a highly technical nature as a to make it desirable for the best interests of the company to have the particular technical division make the commitments. In such instances the technical division should keep the Purchasing Department fully informed of the transaction during its progress.

The third group covers purchases of small quantities of materials or supplies which are not covered by contracts. Materials purchased which can be classified under this group are usually bought by referring to price cards or, if necessary, getting competitive bids by use of telephone. But no Commitments should be made before ascertaining the price from the supplier.

FORMS USED GROUPS 1 AND 2

Commitments for the materials and services classified under items 1 and 2 should be made somewhat along the following procedure:

Request for quotations

Competitive bids should be secured by means of a "Request for Quotation" form. In making up Request for Quotation forms to be

sent to bidders the forms should be so worded as to make conditions the same under which all bids are made, as regards delivery point, F.O.B. point, etc. This should be insisted upon as far as possible.

A "Request for Quotation" form should cover the following:

(1) A—*Article required and quantity.* Where a specific quantity can be stated, it should be. If the business is to run over a period of time, viz: a year, and the quantity is approximate it should be designated as such. Complete specifications and designating numbers should be written on "Request for Quotation" form, or accompany the form on sheets attached with blueprints where necessary.

B—*Service Required.* Covered by detailed specifications of work to be done.

(2) *Manner of Shipment,* viz: by freight, express or truck.

(3) *Shipment Dates.* Shipment dates should be stated where possible or approximate shipment dates.

(4) *Price.* Space should be provided for bidder to set down price and discount terms.

(5) The dates by which the bids must be returned.

(6) Any general information covering above items.

Request for Quotations with specifications and blue prints should be made up in triplicate and sent to bidders in duplicate. One copy of the Request for Quotation form filled out by the bidder should be retained by him, the other is to be returned to the Company. After all bids are in, the business should be awarded to the best bidder taking into consideration price, quality and service. The unsuccessful bidders should be notified to that effect. They are entitled to a reply and such notification minimizes inquiries. Bidders should be made to realize by their dealings with a purchaser that one bid alone is acceptable and that no preferential treatment will be accorded any bidder. In the long run this policy is the only economical one. The business should then be covered by a contract.

CONTRACTS

The major points to be covered are as follows:

In the case of contracts for materials only:

(1) Material (Brand and grade should be specified where possible and any other designation).

(2) Actual or approximate quantity of material to be taken.

(3) Period over which the material is to be taken or dates material is required.
(4) Price, designating F.O.B. point.
(5) Manner of shipment.
(6) Terms, viz.: discounts.
(7) The usual clauses relative to:
  (a) Protecting the buyer against price decline.
  (b) Relative to delays caused by strikes, fires, floods, etc.
  (c) Protecting the buyer against unnecessary delays by seller.
(8) A detailed statement of specifications and blueprints.

In the case of contracts for services:

(1) Work to be done, material to be furnished and the location of the work.
(2) That the work is to be done by competent workmen under competent superintendence.
(3) That the work is to be done under the general supervision of the buying company's representative (usually an engineer).
(4) That all existing structures are to be protected.
(5) That the buyer is to be protected against losses, claims, and suits arising out of the conduct of the work.
(6) That the work is to be done in accordance with all Federal, State, County, City or Township laws and ordinances applying to the work.
(7) That the contractor is to carry insurance protecting him against claims for personal injury and claims covered by Workmen's Compensation Act.
(8) The usual clauses relative to:
  (a) The contractor having examined the site and existing conditions.
  (b) The price to be paid.
  (c) That no payment made in accordance with the terms of the agreement shall be considered to be an acceptance of defective work or improper material.

Contracts for material and services should be made up at least in triplicate, two copies should be executed, one retained by company and one by contractor. The company's executed copy should be retained in the administrative files of the company.

GENERAL

In order to run a Purchasing Department with proper dispatch the following records should be kept:

(1) Commodity record of purchases setting forth on a card for each commodity, names of suppliers who furnish the commodity, dates of quotations and purchases, and prices. This record serves as an index of prices to facilitate prompt purchasing of materials coming under class 3 previously referred to in this paper, "Commitments for Small Supplies, etc.".

(2) An alphabetical record of suppliers, showing purchase order numbers for all purchases by the company.

This paper is intended to cover a method that has been found to work to advantage in purchasing. Probably the majority of concerns securing competitive prices in buying have centralized their purchasing. The forms advocated in this paper, however, will work to advantage in any concern in which some similar forms are not already in use whether the buying is centralized or not and will help distinctly in making a decision when purchases are to be made.

Attached are copies of forms referred to in this paper.

THE BLANK COMPANY

NEW JERSEY

REQUEST FOR QUOTATION

To New Jersey,

Gentlemen:

Kindly quote your lowest prices on the following material:

QUANTITY	ARTICLE	UNIT PRICE	TOTAL AMOUNT

Shipments in
Deliveries
Quote Prices F.O.B.
Via
Bids must be in our hands by
General

The Blank Company

. . . .
By

DELIVER NO GOODS EXCEPT ON PROPERLY EXECUTED ORDER FROM THIS OFFICE

THE BLANK COMPANY

NEW JERSEY

Contract No.........
New Jersey..........

The Blank Company agrees to buy and..
....
....agrees to sell;

PRODUCT:
BRAND:
QUANTITY:
PRICE:
DELIVERY:
PAYMENT:
SHIPMENT:
CONDITIONS:

1. Material delivered under this Contract not in accordance with specifications and or samples submitted will not be accepted. It will be held subject to shipping instructions of Seller.
2. The Buyer is to receive the benefit of any decline in the Seller's regular selling prices on products named in this Contract while the Contract is in force.
3. Payment is to be made by Buyer in New York Exchange, as provided above, for each shipment under this Contract.
4. Shipments under this Contract are subject to strikes, fires, floods, wars, delays or interruptions in transportation by rail or water, requirements or regulations of Government, and all other disabling causes without regard to the foregoing enumeration beyond Seller's control. In such event the Buyer reserves the right to purchase any or all of the undelivered portion of the product elsewhere obtainable and correspondingly reduce the quantities called for under this Contract.
5. In the event of deliveries not being made by Seller as specified under this Contract, due to reasons within the control of the Seller, the Buyer reserves the right to purchase the product in the open market and the damages of the Buyer shall be measured by the difference, if any, between the Contract Price and the market price of the product so purchased to complete this contract.
6. The attached sheets Nos. ...., are a part of this Contract.

ACCEPTED: THE BLANK COMPANY

.........................193 .... By..............................

By..............................

One Copy, Signed by Seller, to be returned to The Blank Company, New Jersey

Contract No..........
Extension No..........

Agreement by and between the Blank Company, New Jersey, hereinafter

called the Company, and ....

....

hereinafter called the Contractor, dated......................................

ARTICLE I

The Contractor Agrees:

1—To supply all labor, tools and equipment necessary to excavate and backfill approximately lineal feet of pipe trench in N. J.

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2—To excavate the trench to the depth and width shown on accompanying Drawing No. this drawing being a part of this Agreement. No changes in depth, width or location of trench shall be made without a written order from the Company's Hydraulic Engineer.

3—To furnish competent superintendence and competent workmen, and to do the work in a workmanlike manner.

4—To do the work as per orders and instructions and under the general supervision of the Superintendent of Construction of the Company, who will define the full meaning of all plans and specifications that are a part of this Agreement, and who will pass upon the workmanship. Should the Contractor fail to properly conduct the work in a manner satisfactory to the Company's Superintendent of Construction, the Superintendent of Construction may then direct the management of the work as provided in the Contract.

5—To use all possible precautions to prevent accidents to persons or property, viz.; through the medium of lights, barricades or dirt piles marking out the trench; watchmen, etc. To properly guard and light the trench if it becomes necessary to leave it open over night.

6—To restore or replace the paving, or to do such paving as agreed to and defined below:

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....

....

To protect all existing pavements, curbing, surface and sub-surface structures. Under no circumstances, and especially after backfilling, shall the trench be left in a condition which in any way would be dangerous to persons or property.

7—To comply will all Federal, State, County, City or Township laws and ordinances applying to or limiting the method and materials used, or actions of those employed on the work.

8—To maintain such insurance as will protect the Contractor from all claims or damages for personal injury, including death, or from such other claims as covered by Workmen's Compensation Act which may arise from operations under this Contract.

9—To completely indemnify, protect and save harmless the Company from any and all losses, claims, suits, and proceedings of whatever nature arising out of the conduct of the work.

Article II

The Company Agrees:

1—To coöperate with the Contractor and lay and caulk pipe as the trench is opened to the required depth, so that the Contractor will be able to backfill the trench without unnecessary delay.

2—To obtain all street opening permits necessary for the execution and completion of the work.

3—To pay the Contractor for the work called for by this Agreement within 30 days after satisfactory completion and final acceptance by the Company's Superintendent of Construction.

Article III

It is Agreed:

1—That the Contractor before delivering his proposal will be held to have examined the site and existing conditions, to have noted any special requirements of the same and to have made in his proposal an allowance to cover all such items. No subsequent allowance will be made because of the Contractor's failure to comply with this requirement.

2—That the unit price per lineal foot of trench to be paid by the Company to the Contractor shall be ($).

3—That no payment made under this Agreement, whether final or not, shall be considered to be an acceptance of defective work or improper material.

4—That delays occasioned by strikes, floods, fires, or other disasters beyond the control of the Contractor shall be considered reasonable delays on the part of the Contractor. However, in urgent cases, where other enterprises and transactions depend upon the performance within a reasonable time of the work called for by this Agreement, the Company reserves the right to have the work performed by another Contractor. In such cases the original Contractor will be paid for the work actually performed on the basis of the agreed unit prices stated in Article III, Paragraph 2, of the Agreement.

Accepted:	**The Blank Company**
....	....
..............................193	193

STATE FRANCHISE TAXES

By Charles J. Tobin[1]

The subject matter of "State Franchise Taxes" is very indefinite. An examination of the State Tax Systems does not comprehend the classification of taxes in the various states under the terminology "State Franchise Taxes." This is so because almost every state deals with the subject matter of taxation as it sees fit. In the classification and terminology of taxes there is no uniformity whatsoever among states. I could give over a large part of this paper just discussing the term "state franchise taxes," but I believe we are not so much interested in the term as we are in the subject matter.

The TANGIBLE property of public utility companies is assessed like other tangible property (ad valorem) in the various states, except in California where the tangible property is assessed on the basis of gross earnings.

DOING BUSINESS

In the various states the measure on the so-called franchise tax for doing business is capital stock, issued and outstanding capital, gross earnings, capital stock and gross earnings, earning capacity in excess of tangibles, gross receipts, gross assets, corporate excess, capital stock and surplus, net income in state, earnings, and capital stock and gross receipts. In Vermont the franchise tax for doing business is considered as a general property tax. The rate of the tax in the various states is as widely different as the measure for the tax—from $2.00 per thousand of capital stock we have all kinds of rates, depending upon the measure of the tax. In a number of states, we have additional franchise taxes on public utilities. These rates differ, depending upon the measure of the tax.

ORGANIZATION

In the matter of organization tax, the measure of the tax is almost entirely capital stock. There are a few exceptions as in Georgia, Pennsylvania and Washington.

[1] Member American Bar and New York State Bar. Dated Albany, N. Y., October 1, 1931.

In the matter of foreign corporations, the license (or franchise) tax is measured by capital employed in the state, capital stock, registration fee, authorized capital stock, full value of the taxable property, value of property employed in the state, capital stock and surplus, annual license fee, and surplus and undivided profits, shares representing property and business in a particular state, flat fee, valuation of property in a state, corporate excess same as domestic corporation, capital stock on business done in a state, and initial entrance fee.

BASIS OF VALUE

The basis for determining the value of "intangible" property, which of course comprehends state franchise taxes, is just as diversified and different as the other taxes I have mentioned above. In Alabama it is the market value of stock and indebtedness minus the value of the tangible. In Arizona, it is the average net over period of years capitalized at given rate of prcentages. In Arkansas it is excess value of shares of stock and bonded indebtedness over value of tangible property. In California, Connecticut, Maryland, Minnesota and Rhode Island, it is gross earnings. In Colorado it is physical value of property, market value of capital stock, mortgage bonds, etc. In Delaware, it is capital stock and net earnings for railroads. In Georgia and Maine, it is gross receipts. In Idaho it is physical valuation of property, capital stock, funded debt, gross receipts and gross expenses. In Illinois, it is value of capital stock, including franchises, over value of tangible property. In Indiana it is excess value of capital stock over assessed value of tangible property. In Iowa it is net earnings. In Kansas it is physical valuation of property, capital stock, gross receipts and operating expenses. In Kentucky it is value of earning capacity, minus assessed tangible property. In Louisiana it is capitalization of net profits covering a period of years. In Massachusetts its value of franchise minus local valuation of real estate and tangible locally taxed is taxed as corporate excess by Commissioner of Corporations and Taxation. In Michigan, Missouri, Nevada, Ohio, Oklahoma, South Dakota, Utah, Washington and Wisconsin, it is physical valuation of property, including franchises. In Mississippi it is true value, taking into consideration value of franchise, capital stock and earnings. In Nebraska, South Carolina, Virginia, West Virginia and Wyoming, it is physical valuation of property. In New Hampshire it is physical valuation of property, market value of stocks and bonds, gross earnings, and

operating expenses. In New Jersey it is for steam railroads physical valuation and franchises. In New York special franchise may be determined by net earnings rule. In North Carolina, it is total taxable value capital stock less value physical property. In North Dakota it is true cash value of property, including franchises. In Pennsylvania it is capital stock and gross receipts. In Tennessee it is market value of capital stock and bonded indebtedness, franchises, gross receipts. In Texas it is franchises and intangibles of railroad and gross receipts. In Vermont it is capital stock, bonded debt, net earnings and physical valuation of property.

This statement of classification, bases and rates will give you some ideas as to how far apart the states are in the treatment of the important subject of franchise taxes.

For twenty-four years the National Tax Association and numerous state associations, economists and representatives of large taxpayers have been endeavoring to bring about some semblance of order in a fair treatment of capital represented in franchises and intangible property situated in the various states of the United States. Each State has the authority to formulate a fiscal program and to levy or authorize the levy of taxes for cost of government. Some features of the tax programs of the several states are common to all, but in many respects they are entirely dissimilar. In the beginning those differences were not so material; business in those days was principally local. Means for rapid transportation and communication did not exist. Business is now national in its scope. It does not recognize the artificial boundary lines of states and much less those of the municipalities within states. Although in the earlier years a measure of uniformity of taxation was desirable, it was not imperative. Today each of the 48 states is in competition with the other 47. If one state elects to impose an unjust or unduly heavy burden on capital, capital will not flow into that state for the development of its natural resources and industries. Business and capital are now more selective in choosing the states or the localities within the state where they will locate. It is desirable from every standpoint that there should be at least a fair degree of uniformity in state tax laws. In fact, it is believed reasonable to say that, with the exception of tax rates, a model system of state and local taxation can be devised and made generally adaptable to all American states. That would not imply, of course, that every state must have every kind of a tax embraced within the model system. If, for instance, the model

system should include an income tax and a given state did not desire that kind of a tax, but preferred in its place higher rates on other kinds of taxes, it could decide to exclude the income tax. What we need is a comprehensive statement of all our tax problems. I will attempt to state a few of them. They are as follows:

1. The determination of model constitutional provisions.
2. The determination of the difference between the present system and the correct system of taxation.
3. The determination of proper administration methods.
4. The reconsideration of the assignment of functions between the various orders of government.
5. The determination of various standard dates, standard years, etc.
6. The determination of the problem of securing the best possible administration of various taxes in each state.

UNDERLYING PRINCIPLES OF TAX LAWS

A study of the tax laws of the American states reveals the fact that there are *three* fundamental principles which have been more or less clearly recognized by our law makers and have largely determined the basis of the enactments now standing on the statute books.

The first is the principle that every person having taxable ability should pay some sort of a direct personal tax to the government under which he is domiciled and from which he receives the personal benefits that government confers. This is most clearly exemplified by the laws providing for the taxation of securities and credits which represent in large part interests in tangible property and business located in other jurisdictions. In spite of the fact that such laws may lead to unjust double taxation, most of the states have insisted upon taxing evidences of ownership, upon the theory that the owners are within their jurisdiction and receive from them certain personal benefits which justify the imposition of a tax. Some states will have to change their present taxes to meet Farmers Loan and Trust Co. vs. Minnesota 280 U. S. 204. State income tax laws usually proceed upon a similar principle; and the same may be said of the poll tax, which is still found in many of the commonwealths.

The second principle is that tangible property, by whomsoever owned, should be taxed by the jurisdiction in which it is located, because it there receives protection and other governmental benefits

and services. That the owner is frequently a non-resident is not considered a material fact, because the property must be protected where it is located, and, if employed in trade, comes in competition with similar property of residents. This principle, furthermore, has received the sanction of the Supreme Court of the United States in cases which have developed the rule that tangible property is taxable in the jurisdiction within which it is located, and not elsewhere.

The third principle, somewhat less clearly and generally exemplified by our tax laws, but discernible none the less, is that business carried on for profit in any locality should be taxed for the benefits it receives. If the owners of the business are residents of the state, this principle need not be appealed to, since the ordinary methods of taxation may be considered to provide for such a case. If a considerable amount of real estate and other tangible property is employed in a business conducted for the account of non-residents, again no appeal may be made to this principle, since here too the ordinary methods of taxation may be considered adequate. But if the owners are non-residents, and the business, though very profitable, employes little or no property subject to taxation in the locality, the state, to an increasing degree, demands that some method shall be devised for reaching such business enterprises. This tendency is exemplified in the taxation of corporate franchises in California and some other states, in the taxes imposed on incomes in Wisconsin and some other commonwealths, and in such laws as that enacted by Louisiana taxing non-residents upon credits arising from business done within that state. It finds, further, an even more general expression in the numerous business taxes, usually in the form of licenses, which are found in many states, particularly in the South.

Whatever one may think of any or all of these principles, the fact remains that they undoubtedly represent hard facts which any new system of taxation must take into account. That they are not in many cases logically and consistently applied, admits of no doubt; that they sometimes lead to confusion, and involve unjust double taxation and disregard of interstate comity, cannot be questioned.

In the consideration of the problem of a uniform "state franchise tax," such tax must embrace a system that provides that:

1. All persons shall be taxed fairly and fully at their place of domicile for the personal benefits they derive from government;

2. All tangible property which any state may desire to tax shall be taxed fully at its situs for the governmental services it there receives;
3. The intangible of corporations should not be assessed as property because such taxation cannot be carried out without a large amount of unjust double taxation;
4. The states should be permitted to tax intangibles—whether expressed in a franchise tax, a license tax, a business tax or whatever other classification they care to make, in a manner that establishes equity between the companies organized within their state and the companies coming into the state to do business in competition with the domestic corporations.

TREND OF WATER RATE STRUCTURE IN MICHIGAN CITIES

By G. D. Kennedy[1]

A committee composed of Charles R. Bettes, Philander Betts, A. E. Blackmer, A. W. Cuddeback, James L. Tighe and Allen Hazen presented to the New England Water Works Association in 1914 a form of water rate structure which was adopted as a standard after extended discussion on November 6, 1916. It was a modification to fit current practice with the least possible disturbance of the better feature of the Coffin report made to the New England Association a decade earlier.

In practically identical form this standard was adopted by the American Water Works Association after a series of committee reports on May 24, 1923. With at least nineteen years of background, during which period the fundamentals were clearly understood and effects studied before its adoption, it is interesting to note its rapid and wide spread application during the seven years since this Association stamped it with its approval. In 1925 a partial list of American cities having adopted the standard form published in the Manual included only 15 names.

It is the purpose of this paper to point out briefly its effect on water rate structures in a single one of the forty-eight states, namely, Michigan. In connection with a water rate study made for Pontiac, Michigan, a city of 65,000 inhabitants, during the last three months of 1930, a questionnaire was sent out to the twenty-five largest cities of the state, ranging from 1,573,985 to 12,533. Data from this questionnaire are presented here.

The cities replying and their population, according to the 1930 census are, as follows:

Detroit	1,573,985
Grand Rapids	168,234
Flint	156,422

[1] Civil Engineer, Department of Water Supply, Pontiac, Mich.

Saginaw	80,409
Lansing	78,492
Pontiac	64,608
Hamtramck	56,283
Jackson	54,870
Kalamazoo	54,707
Highland Park	52,817
Dearborn	50,060
Bay City	48,935
Battle Creek	43,301
Muskegon	41,338
Port Huron	31,176
Wyandotte	28,394
Ann Arbor	26,867
Royal Oak	22,122
Ferndale	20,796
Monroe	18,090
Owosso	14,496
Holland	14,349
Adrian	12,891
Traverse City	12,533

The standard form of rate schedule as it appears on page 461 of the Manual of Water Works Practice incorporates a sliding scale, now quite generally used by other utilities such as gas and electric and a service charge. Three or four steps are provided, the quantities of water per quarter allowed in each being 10,000 cubic feet, 90,000 cubic feet, 900,000 cubic feet and the fourth step all over 1,000,000 cubic feet. The actual amounts to be charged per cubic foot for any given period are not stipulated, but are left for individual determination to produce the required amount of revenue to meet proper costs. The service charge is dependent upon the size of meter installed and the ratios of service charges between meters of various sizes should be in proportion to their relative capacities.

The entire Michigan rate schedules are shown in table 1, as clearly as can be without extensive footnotes to indicate minor exceptions where local conditions are slightly different. A study of the table obviates the necessity of extensive discussion. Seventeen of the 24 cities reporting have adopted a service charge depending on the size of meter used. In the cities where a minimum bill is charged varying amounts of water from 3000 gallons to 2500 cubic feet are allowed on payment of minimum.

All cities questioned have at least two steps of a sliding scale; all but two have three or more; eleven have not adopted a fourth step.

TABLE 1

Water rates in Michigan cities

MINIMUM BILL OR SERVICE CHARGES (RATE IN DOLLARS PER QUARTER)										CITY	SLIDING SCALE OF WATER RATES							
											First Step		Second Step		Third Step		Fourth Step	
⅝ inch	1 inch	1¼ inches	1½ inches	2 inches	3 inches	4 inches	6 inches	8 inches	10 inches		Rate*	Quantity*	Rate	Quantity	Rate	Quantity	Rate	Quantity
2.40	7.20		14.40	24.00	33.60	43.20	72.00	110.00	158.40	Detroit	.65/1000	10,000	.50/1000	90,000	.40/1000	Over 100,000		
7.00	11.00	16.00	20.00	32.00	112.00	200.00	444.00			Grand Rapids	.11/100	1,100	.105/100	8,900	.10/100	40,000	.095/100	50,000
2.25	3.36		5.61	7.86	27.54	48.90	109.11	210.36		Flint	.15/100	10,500	.11/100	10,500	.08/100	Over 21,000		
1.50	1.80	2.40	4.50	7.20	25.00	45.00	99.00	135.00		Saginaw	.20/133	667	.15/133	12,667	.14/133	53,333	.13/133	133,333
.65	1.25		2.00	2.50	5.00	10.00	18.00	30.00		Lansing	.12/100	6,000	.11/100	9,000	.095/100	15,000	.08/100	75,000
.25	.50	.75	1.00	1.50	4.00	5.00	8.00	10.00	15.00	Pontiac	3.50/2000	2,000	.90/1000	Over 2,000				
1.20	3.60		7.20	12.00		21.60	36.00	55.20	79.20	Hamtramck	.95/1000	5,000	.90/1000	5,000	.80/1000	Over 10,000		
1.00	2.00	3.00	3.00	5.00	10.00	15.00	30.00			Jackson	.90/1000	10,000	.85/1000	90,000	.55/1000	900,000	.40/1000	1,000,000
.80	2.00		3.50	6.00	11.00	20.00	40.00			Kalamazoo	.09/100	10,000	.065/100	90,000	.04/100	Over 100,000		
1.25	Min. bill†									Highland Park	1.25/1000	1,000	.70/1000	Over 1,000				
2.00	Min. bill									Dearborn	2.00/1000	1,000	1.10/1000	3,000	.85/1000	14,000	.84/1000	12,000
1.70	3.10	4.45	5.60	8.00	15.00	23.00	43.00	50.00		Bay City	.14/100	10,000	.09/100	40,000	.065/100	Over 50,000		
1.50	3.00		9.00	12.00	20.25	26.25	47.50	99.00		Battle Creek	.16/133	6,000	.15/133	6,000	.14/133	48,000	.13/133	60,000
2.25	Min. bill									Muskegon	.12/100	50,000	.10/100	50,000	.08/100	50,000	.06/100	Over 150,000
.25	.75		1.50	2.00	3.00	4.50	7.00	10.00	15.00	Port Huron	.675/1000	4,000	.5625/1000	36,000	.375/1000	40,000	.2625/1000	80,000
.60	1.80		3.60	6.00	8.40	10.80	18.00	27.60	39.60	Wyandotte	.21/133	6,667	.17/133	13,333	.10/133	Over 20,000		
1.50	Min. bill									Ann Arbor	.15/100	1,500	.09/100	98,500	.06/100	Over 100,000		
2.00	Min. bill									Royal Oak	2.00/700	700	.20/100	10,000	.16/100	Over 10,700		
1.60	Min. bill									Ferndale	1.60/700	700	.15/100	300	.14/100	900	.13/100	12,000
2.20	5.50	8.30	9.75	14.00	28.00	42.00	70.00			Monroe	2.20/600	600	.30/100	800	.24/100	12,600	.18/100	126,000
3.50	8.00		10.00	16.00	25.00	48.75	115.00			Owosso	3.50/900	900	.13/100	11,100	.08/100	Over 12,000		
1.50	3.50		5.00	8.50	17.50	25.00	35.00			Holland	.11/100	50,000	.10/100	50,000	.09/100	50,000	.07/100	Over 150,000
2.50	Min. bill									Adrian	.32/133	12,000	.24/133	12,000	.19/133	24,000	.16/133	Over 48,000
.25	.50	.50	.50	.75	1.00		1.50			Traverse City	.60/1000	6,000	.525/1000	6,000	.45/1000	48,000	.375/1000	60,000

* Rate = dollars per cubic foot. Quantity = cubic feet per quarter.

† Minimum bill.

In addition to the cities shown in the tabulation, seven cities have added extra steps, one Michigan city having as high as nine steps for its customers.

As to form, it may be said, therefore, that about fifteen Michigan

TABLE 2
Quantity rates compared on A. W. W. A. rate structure
(Figures show prices per 1000 cubic feet)

NAME OF CITY	FIRST STEP (10,000 CUBIC FEET PER QUARTER)	SECOND STEP (90,000 CUBIC FEET PER QUARTER)	THIRD STEP (900,000 CUBIC FEET PER QUARTER)	FOURTH STEP (ALL OVER 1,000,000 CUBIC FEET PER QUARTER)
Detroit	0.65	0.50	0.40	0.40
Grand Rapids	1.06	0.99	0.86	0.85
Flint	1.50	0.84	0.80	0.80
Saginaw	1.24	1.04	0.91	0.90
Lansing	1.05	0.71	0.63	0.60
Pontiac	0.90	0.90	0.90	0.90
Hamtramck	0.92½	0.80	0.80	0.80
Jackson	0.90	0.85	0.55	0.40
Kalamazoo	0.90	0.65	0.40	0.40
Highland Park	0.76	0.70	0.70	0.70
Dearborn	1.04	0.85	0.85	0.84
Bay City	1.40	0.76	0.65	0.65
Battle Creek	1.17	1.02	0.83	0.61
Muskegon	0.86	0.80	0.62	0.60
Port Huron (5 percent metered)	0.61	0.46	0.15	0.11
Wyandotte	1.50	0.81	0.75	0.75
Ann Arbor	0.99	0.90	0.60	0.60
Royal Oak	2.00	1.60	1.60	1.60
Ferndale	1.10	1.00	1.00	1.00
Monroe	2.45	1.82	1.23	1.20
Owosso	1.30	0.82	0.80	0.80
Holland	1.10	1.04	0.71	0.70
Adrian	2.40	1.37	1.20	1.20
Average	1.060	0.812	0.673	0.641

cities of the twenty-four largest have adopted the American Water Works Association standard form with only slight modifications. If anywhere near this percentage pertains in other states of the union it is an indication that extremely rapid progress has been made since the publication of the Manual in 1926.

Since the amounts in table 1 vary with the quantity of water allowed in each step, they have been reduced to the quantities allowed in the standard rate steps and table 2 shows the equivalent amount charged.

Certain general relationships between the four steps have been offered in the Manual, namely, that the third step should be one-half the first, the fourth one-third the first and the second equal to the average of the first and fourth. Accordingly the average step rates should have had the following relationships:

	FIRST STEP	SECOND STEP	THIRD STEP	FOURTH STEP
Actual Average step rates of Michigan cities	1.06	0.81	0.67	0.64
Relationship according to general rules	1.06	0.70	0.53	0.35

From the somewhat higher scale that actually does exist in the upper steps it may be assumed that water supplies are expensive to develop in Michigan. Another explanation which undoubtedly is a factor is that the people do not like too great a difference in the quantity rates charged small and large consumers.

References to the development of the standard form of rate structure are taken from Allen Hazen's "Meter Rates for Water Works" published in 1918 and from the "Manual of Water Works Practice" of this Association.

ACCOUNTING RECORDS FOR PHYSICAL PLANT

By E. E. Bankson[1]

The burden of my topic to-day is to recall that the grave need for better recording of physical plant, as fixed capital, is a ringing challenge to the water works profession.

Experience of the writer, on appraisal and valuation work, would indicate that the progress made in the recording of fixed capital has not kept pace with the needs of the times, and this discussion is being offered as an appeal, to water works men generally, for equally rigid requirements in the recording of physical plant detail as in the recording of exact dollars and cents expended.

While I hold no brief for any particular method, or system, of records, or have any criticism of insufficient existing records, I do feel at liberty to raise my voice with those who call for better records of physical property and to lend a hand in the direction of fundamental and sufficient data; without going to the extreme of unnecessary detail and prohibitive recording costs.

Apparently, all accountants clearly realize their responsibilities regarding the funds expended for plant account, to the exact red cent; but relatively few, on the other hand, are possessed with sufficient urge or time to provide complete detail record of physical plant, as between the monies expended and the physical units or structures created.

This permanent record of detail quantities and character is so highly desirable, in the field of valuation work, in relation to plant depreciation, and in relation to plant retirement that economy and value would surely result from a more widespread application of detail and clarified accounting for physical plant, as fixed capital. The absence of more general attention to this feature is possibly due to the great numbers of water plants, isolated from each other and under the management of local men not greatly concerned over these plant records.

In days gone by, speaking generally, the accountants were held responsible for record of money transactions in revenues and expendi-

[1] Consulting Engineer of The J. N. Chester Engineers, Pittsburgh, Pa.

tures, without specific regard to the physical details involved, and without regard to the intimate relation between these physical or quantity factors and the elements of cost. As the complexities of utility regulation increase, however, and as our plants grow old, to replacements, it becomes more and more evident that all accounting, in this field of endeavor, should record certain fundamental physical data, if justice is to be done, with economy.

Any thought that municipal waters works do not fall in this class ignores the fact that municipal plants in some states are also regulated by a utility or service commission. Even in Pennsylvania, where municipal plants are not regulated by the Public Service Commission, the City of Pittsburgh has had two court cases, within recent years, where complete data on fixed capital of water works was required.

(1) For, Valuation Work, we find the accounting records often lacking in any clew as to original conditions or difficulties affecting the cost or extent of construction, or as to the exact quantity, or units, of construction work, covered by the amount of expenditures entered in the account, except as may sometimes be contained in an engineer's final estimate of construction work done, and the cost, thereof, where the work was done by contract.

For instance, on a recent appraisal, the records gave no indication that a certain conduit was laid under most difficult and costly conditions, and it was only by the memory of man that such evidence is to-day available, to a true value of the plant item in question. Not only are memories partly indefinite, and sometimes unreliable, but the old timers are passing on, and certain evidence is forever lost, only because the facts were not accounted by permanent, or perpetual, records.

Not only should complete quantities of excavation be recorded for foundation of structures and in trenching for water lines, but the specific location, dimensions, and quantities of rock should be recorded; together with all other conditions, encountered, which create substantial extra construction costs. It is unfair to expect an appraiser to piece together a complete and accurate record, of special conditions, by the aid of uncertain memories of employees, or after those memories have passed on.

If record is being made of an expenditure in the amount of $176.92 for certain concrete construction, it is of *more* importance that the record show "10.6 cubic yards of 1:2:4 reinforced concrete in 8-inch walls" than it is to show that this physical item did cost $176.92,

although I seem to have found many persons who do not think of the accounting records going beyond the feature of dollars and cents. If we are recording the cost of certain concrete work, let the records describe and measure that concrete; if we are recording the cost of a certain piece of equipment, let us describe, measure, and label that piece of equipment; and if we are recording cost of a length of pipe line, in trench, let us describe, measure and classify all of the costs for labor and materials required on the work.

A recent case, in point, is where two appraisal reports had failed to record those quantities of earth and concrete, on dam construction, required to fill the old rock gorge of the original stream bed, no longer in evidence; and it was only through chance remarks by the Contractor, on later day work, that this value was reclaimed to the property, on subsequent valuation report. Rock in trench, lowering of mains, paving cuts, and many special types of costly work are lost from plant value, unless preserved in the records, since it is too costly and often impossible to completely re-establish the evidence of the fact in question.

(2) Since recent actual cost is the best legal evidence of present day production cost, it would be very helpful, indeed, if more of the record costs were attached to its particular unit or feature, rather than merely to the account number; and divided as to labor and materials. For instance a certain substantial water company has kept cost data on individual service lines during only one year of its entire existence, prior to purchase by a holding company; and that work was done outside of the accounting department. Again, only the old letter files of this same company provide the engineer's statement of work done by contract on a certain impounding dam, but not including item or items for clearing and stripping of reservoir basin. It is the presumption that clearing and stripping was done by day labor, but the records should have provided that information; including the conditions and extent, or specifications for the work.

(3) Since such items as extra cost of rock excavation in trench and cost of repaving work over mains do not depreciate concurrently with the plant item, the record of accounts should maintain these costs separately, and in detail, for proper disposition in the future, together with exact measurements for each kind or type of material encountered.

Labor cost on trenching and laying mains should be kept separately in order that it be useful as a guide in prospective estimates or for

TABLE 1

Shreveport, La. Contract costs. (March, 1930.) Filtration Plant and Pumping Station*

8 m.g.d. filtering capacity, in 4 units, at filtering rate of 2.5 gallons per minute per square foot and 3 hours sedimentation basin, with clear water basin entirely separate; of 1 m.g.

	TOTAL AMOUNT*	COST PER MILLION GALLONS
Item No. 1.1. Excavation, grading, etc.		
Sedimentation Basin:		
Clearing site	$260.00	
5400 cubic yards of earth excavation	4,520.00*	
20.4 cubic yards of rock excavation, extra	62.90	
5750 cubic yards of backfill and grading	3,650.00	
700 cubic yards of earth, extra	450.00	
1540 square yards of sodding	416.00	
Total sedimentation basin	$9,358.90	$1,169.
Filters:		
Clearing site	$130.00	
970 cubic yards of earth excavation	810.00	
40 cubic yards of earth excavation, extra	63.50	
1920 cubic yards of backfill and grade	1,206.00	
260 cubic yards of backfill and grading, extra	154.00	
900 square yards of sodding	244.00	
Total filters	$2,607.50	$326.
Pumping station (with C.W.B.):		
Clearing site	$100.00	
1230 cubic yards of excavation	1,025.00	
2880 cubic yards of backfill	1,812.00	
460 cubic yards of backfill, extra	298.00	
640 square yards of sodding	173.00	
Total pumping station	$3,408.00	$426.

* Prices applying as follows: Common labor at 35 cents on construction and 25 cents on trenching; carpenter at $1.125 per hour; sand at $2.25 per cubic yard of 2700 pounds; gravel at $2.65 per cubic yard of 2700 pounds; cement at $2.42 per barrel; concrete intake pipe, base at $41.00 per ton Shreveport, La.; brick at $16.00 common and $45.00 face; brick masons at $1.50 per hour; 1:2:4 reinforced concrete at $13.80 per cubic yard plus steel below;——plain concrete at ——; reinforced steel at 4.43 cents per pound in place; structural steel at 11.4 cents per pound (in place); etc.; etc.

TABLE 1—*Continued*

	TOTAL AMOUNT*	COST PER MILLION GALLONS
Item No. 1.1. Excavation, grading, etc.—*Concluded*		
Clear Water Basin (1 m.g.):		
Clearing site	$160.00	
3900 cubic yards of excavation	3,255.00	
60 cubic yards of rock excavation	282.00	
950 cubic yards of backfill	600.00	
600 cubic yards of sodding	163.00	
Total clear water basin	$4,460.00	$558.
Roads, Walks and Lawn:		
14200 square feet of roads and walks	3,009.00	
1075 cubic yards of earth and 4.9 cubic yards of concrete	1,072.50	
820 square yards of sodding	206.00	
Total roads, walks and lawn	$4,287.50	$536.
Item 1.2-A. Intake line		
668 lineal foot of concrete intake	$38,307.00	$4,788.
Item 1.3. Concrete work, etc.		
Sedimentation Basin:		
1452 cubic yards of concrete	$32,400.00	
Channel frames, south end	58.53	
Wood baffles	55.28	
Total sedimentation basin	$32,513.81	$4,064.
Filters:		
527 cubic yards of concrete	$11,800.00	
6.7 cubic yards of concrete, extra	141.00	
Total filters	$11,941.00	$1,493.
Pumping Station (with C.W.B.): (3 walls only)		
435 cubic yards of concrete	$9,800.00	
6 cubic yards of concrete, extra	126.00	
Total pumping station	$9,926.00	$1,241.
Clear Water Basin (with pump station): (Charging common wall here)		
1089 cubic yards of concrete	$24,300.00	
Extra work order	88.00	
Total clear water basin	$24,388.00	$3,049.

TABLE 1—*Concluded*

	TOTAL AMOUNT*	COST PER MILLION GALLONS
Item 1.4. Outside piping and drains		
170 tons pipe and 56 tons specials	$35,233.65	
9 1-inch extension stems	46.00	
8 catch basins and drains	451.24	
Total item 1.4	$35,730.89	$4,466.

valuation work. That is, we should have labor costs, separated for such items as hauling, trenching, laying backfilling, lifting paving repaving, etc., together with the data for rock excavation and any similar costs created by special conditions; including the necessary measurements or data for computation of all physical quantities, labor rates involved, grade or type of materials employed, and all fundamental information which would just naturally result, if the recorders would only acquire the *habit*, or *hobby*, of recording such information. *Inspiration* and *habit* are the necessary *human* elements, and when these elements are combined with a sufficient amount of time and purpose, one would expect satisfactory records to result.

(4) For an intelligent analysis of plant depreciation, it is necessary or desirable to record more than mere dollars and cents expended under each classification, in order that depreciation may be fixed, with some satisfaction, for each plant item or unit.

We are possibly all acquainted with a certain school of thought which holds that annual depreciation should be applied as a composite percentage for the entire plant in question, rather than on each item separately, but that idea seems to beg rather than to master the question, and, in any case, the details are generally required for the settlement of any controversies over rates.

The more recent policy of the Federal Tax Unit, to the effect that depreciation would be allowed only on properly classified accounts, offers further support to the contention that fundamental segregation and quantity-quality description should be at hand.

(5) In planning finances for proposed construction and in scrutinizing the resulting costs of new construction, it is most helpful to have at hand an analysis of costs on other similar work done under com-

TABLE 2

Commissioners of Water Works in the City of Erie, Pa. Summary of cost of laying mains year 1921 in cents per lineal foot. Class "C" pipe—laid 5-foot cover

MONTH	LOCATION	LENGTH	PIPE	SPECIAL	SUPPLIES	TEAM AND TRUCK	TRENCH HAND	MACHINE TRENCH	LAY AND CALK	BACK FILL	GENERAL LABOR	FOREMAN	STANDARD DEPRECIATION OVERHEAD	COST PER FT.
	6-inch size													
		ft.	¢	¢	¢	¢	¢	¢	¢	¢	¢	¢	¢	¢
	Forward	12,199												
November	21st, Cranberry West	440	80.8	11.4	06.3	00.2	03.0	29.1	02.8	13.7	02.8	03.3	13.0	166.4
	30th, Rasp West	141	76	31.4	07.9	13.9	27.1		04.0	10.5	01.4	09.4	24.4	206.0
	South Shore Drive, Shenley Drive West	356	76.4	07.0	06.2	03.6	12.4	18.1	02.7	7.3	02.2	04.7	12.4	153.0
December	Shenley Drive West, Lake Road North	2,548	76.6	06.5	06.2	01.6	09.5	10.0	03.2	8.8	01.3	02.2	10.2	136.1
	Glenwood Boulevard and Cherry	235	76.8	25.5	07.7	01.8	52.2		06.9	16.7		22.3	42.6	252.5
	Lincoln Avenue, Olland Drive North	300	76.5	05.8	10.8	01.1	06.9	19.0	02.5	15.2	03.0	03.8	17.5	162.1
	Glenwood Boulevard and Alley	140	76	30.0	08.1	01.3	34.6		09.4	09.0		09.2	27.8	205.4
	Kahkwa West, Lake Road North	1,816	76.5	10.1	06.3	01.2	07.9	20.9	02.9	9.9	01.1	02.9	12.9	152.6
	Evan Street and Peach	567	75.8	16.5	06.4	03.7	10.5	24.7	04.2	25.0	02.2	08.6	26.0	203.6
	Grands Boulevard and Cherry	37	81.4	165.8	20.5	18.2	53.8		11.7	16.4	02.8	25.1	53.5	449.2
	6st, Lincoln Avenue West	184	76.4	34.7	09.2	04.0	22.0		05.2	12.2		13.2	24.1	201.0
	Total	18,963	88.1	13.5	07.2	02.4	13.1	20.0	05.1	12.7	01.9	04.7	18.5	187.4

		12-inch												
May	Perry, 31st South	59	256.3	07.0	13.5		26.7		30.9	32		12.9	51.4	431.0
September	Holland, 33d to Cooper	1,580	260.2	28.0	06.4	05.2	06.1	24.0	11.7	12.6	09.0	03.6	18.9	385.7
October	Water Street Subway	889	86.2	06.5	16.1	07.3	82.9		11.3	12.2	10.7	09.9	47.8	290.9
	Pearl Street and Water Street	790	177.1	31.2	18.0	02.7	38.1	23.7	09.9	17.3	03.3	09.3	25.8	365.7*
	Total (see note)........................	3,318	193.7	22.6	11.9	05.1	34.7	17.1	11.5	07.9	08.0	06.8	28.9	356.4

Note: These figures should not be used as a representative cost of laying 12-inch mains for reason of Jobs 3242 and 3260 were laid with salvaged pipe and other material, at cost of salvage.

		16-inch												
(1920) (1921) July	Richley Street to Cooper Road and Holland	4,840	418.2	31.3	09.0	07.0	61.5	18.0	17.4	20.9	05.1	09.3	44.5	646.4
		4-inch												
December	Dividing line of Fern-Cliff and Kahkwa Park	439	73.2	02.2	04.0	00.5	17.1		03.4	12.2		09.7	18.6	140.9
		2-inch												
July	Boston Street West of Brown's Avenue	201	27.9	03.7		00.7	24.3		03.2	09.6	02.4	04.1	14.6	90.5

* Including miscellaneous at 9.3 cents for 790 feet.

TABLE 3

Unit labor costs 6-inch pipe, Kansas City, Mo., Water Department, laid during fiscal year 1926

CLASSIFICATION	TOTAL COST	COST PER LINEAL FOOT	71,606 LINEAL FEET 6 INCH MAIN			
			Unit quantities	Unit cost	Man days	Unit per man day
1. Excavation:						
Digging trench in earth, 57,370 feet	$17,819.10	$0.311	19,123 cu. yds.	$0.931	3,718	5.17 cu. yds.
Digging trench in rock:						
Ledge rock blasted 6,980 feet	8,210.18	1.175	1,882 cu. yds.	4.36	1,622	1.16 cu. yds.
Loose rock shale. Not blasted, 6,800	3,869.78	.568	1,834 cu. yds.	2.11	669	2.74 cu. yds.
Cutting pavement:						
Concrete 4,784 feet	917.82	.192	1,063 sq. yds.	.862	190	5.6 sq. yds.
Macadam 4,752 feet	472.25	.099	1,055 sq. yds.	.448	97	10.9 sq. yds.
Backfilling 71,606 feet	8,762.19	.122	22,839 cu. yds.	.383	1,740	13.1 cu. yds.
2. Pipe work:						
Laying and calking	4,784.27	.067	71,606 lin. ft.	.067	932	76.8 lin. ft.
3. Pavement repair:						
Asphalt top				3.00*		
Brick				5.50*		
Concrete				3.75*		
Macadam				3.00*		
4. Supervision (foreman only)	5,143.14	.072	71,606 lin. ft.	.072	824	86.7 lin. ft.
5. Contingencies	4,537.37	.063	71,606 lin. ft.	.063		
Total cost per foot in earth		$0.635				
Total cost per foot in solid rock		1.499				
Average hourly wage		.638				

Number of hydrants set 174. Main per hydrant, 412 lineal feet.

Number of valves set on mains, 100. On hydrant branches 174.

Main per line valve 716 lineal feet.

Powder used 1,106 pounds. Rock removed per pound of powder, 1.7 cubic yards.

* Prices paid street repair department per square yard.

Powder used 1,106 pounds. Rock removed per pound of powder, 1.7 cubic yards.
* Prices paid street repair department per square yard.

TABLE 4

Bureau of Water, City of Pittsburgh—Report of Appraisal as of January 1, 1928. Distribution Division, Pipe Line Section. Unit cost for pipe lines—1870 to 1919

	SIZE OF PIPE, INCHES												
	4	5	6	8	10	12	14	15	16	20	24	30	36
Weight, pounds per foot													
Pipe	24.00	31.17	38.83	53.92	77.67	101.50	127.00	145.80	160.92	222.42	284.33	276.50	502.42
Add 2 percent overweight	.48	.62	.78	1.08	1.55	2.03	2.54	2.92	3.22	4.45	5.69	7.53	10.05
Add specials 2 percent	.48	.62	.78	1.08	1.55	2.03	2.54	2.92	3.22	4.45	5.69	7.53	10.05
Total weight	24.96	32.41	40.39	56.08	80.77	105.56	132.08	151.64	167.36	231.32	295.71	391.56	522.52
Lead weight	.67	.83	1.00	1.33	1.67	2.00	2.33	2.50	2.67	3.33	4.00	5.00	6.00
Costs per foot													
Pipe	$0.365	$0.475	$0.591	$0.821	$1.183	$1.546	$1.934	$2.220	$2.451	$3.387	$4.330	$5.734	$7.651
Specials	.013	.016	.021	.029	.041	.054	.067	.077	.085	.118	.151	.200	.270
Hauling	.015	.019	.024	.034	.048	.063	.079	.091	.100	.139	.177	.235	.314
Lead	.034	.042	.050	.067	.084	.100	.117	.125	.134	.167	.200	.250	.301
Laying	.343	.330	.330	.409	.986	.712	.890	.980	1.067	1.820	1.600	2.173	2.040
Valves	.032	.041	.051	.076	.111	.142	.235	.158	.183	.284	.436	.271	.410
Valve boxes	.053	.053	.053	.053	.053	.053	.053	.029	.029	.029	.029	.010	.010
Hydrants	.060	.060	.060	.060	.060	.060	.060	.060	.060	.060	.060	.060	.060
	$0.915	$1.036	$1.180	$1.549	$2.566	$2.730	$3.435	$3.740	$4.109	$6.004	$6.983	$8.933	11.056
Miscellaneous 18.6 percent*	.170	.193	.219	.288	.477	.508	.639	.696	.764	1.116	1.299	1.662	2.056
Total	$1.085	$1.229	$1.399	$1.837	$3.043	$3.238	$4.074	$4.436	$4.873	$7.120	$8.282	$10.595	$13.112
Unit cost per foot†	1.10	1.25	1.45	1.90	2.60	3.25	4.10	4.45	4.90	6.60	8.25	10.70	13.15

* As shown on previous page.
† See following page and explanation of Basis for Costs.

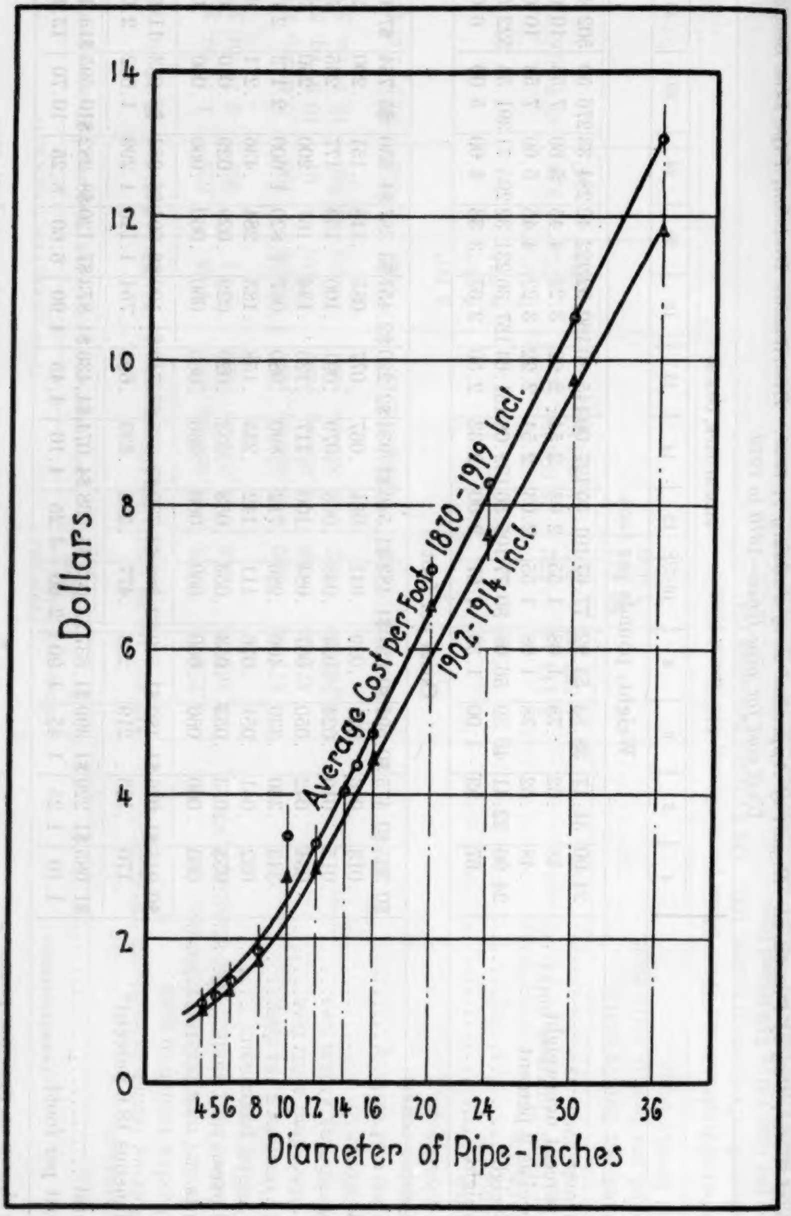


FIG. 1. CURVES SHOWING AVERAGE COST PER FOOT FOR CAST IRON PIPE LINES

TABLE 5

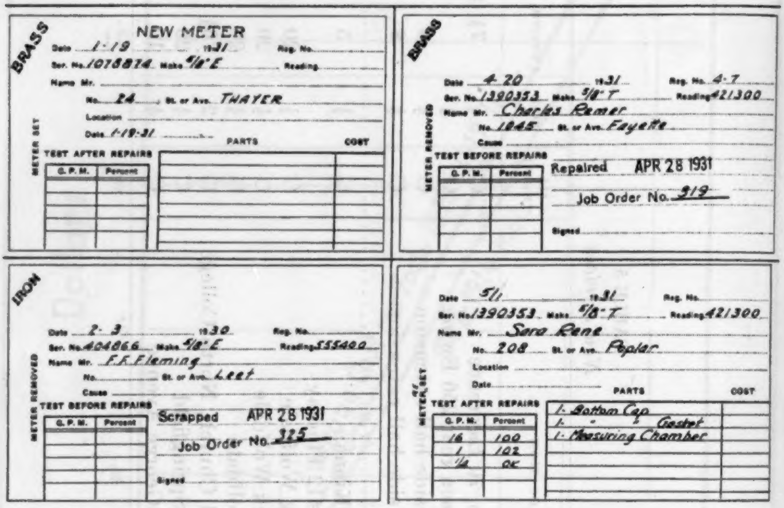
New services

NUMBER	DATE	LOCATION	MATERIAL	SIZE	LENGTH	INVENTORY COST	OTHER MATERIAL	LABOR COST	REPAVING COST	TOTAL COST
259	July 16	Russell W. Harris, 70 Lawrence	C	½	7½	$4.44		$0.45		$4.89
260	August 1	Thos. W. Henderson rear 256 Ewing	G	½		2.28		1.00		3.28
261	July 18	Vacant lot south side hall extension	C	½	8	4.58		4.27		8.85
262	July 18	Vacant lot south side hall extension	C	½	8	4.58		4.49		9.07
...	...	...	...	...	...	...	...	...	...	...
436	November 2	Claud rear 43 McKinnan	G	½	5	2.56				2.56
437	November 2	William Merritt, 412 Findlay								
438	November 15	Frank A. Dittrick Wolfdale	G	½	20	3.90		5.00		8.90
439	November 15	Arthur C. Dittrick Wolfdale	G	½	20	3.90		4.60		8.50
440	November 15	Frank Stanley Wolfdale	G	½	20	3.90		4.60		8.50
441	November 15	Trinity Episcopal Church, North College	G	2	6½	9.79		11.21	25.78	46.78
442	November 18	S. E. Water, 293 Springfield	C	½	20	9.25		8.99	19.80	38.04
443	November 16	Emma Black, McGeorge Avenue	C	½	10	4.75		5.39		10.14

parable conditions; and since two cases will seldom be found to be identical, an intelligent comparison can be made only on the basis of a full record for fundamental conditions, quantities, quality and type.

Without further citation, and without any attempt to describe or outline a model plan for such records of property, and cost thereof, I am persuaded to offer a few samples of data and record, as representing certain effort, in different offices, towards a solution of some one problem.

CITIZENS WATER COMPANY, WASHINGTON, PA.



BRASS
NEW METER
METER SET
Date 1-19 1931 Reg. No.
Ser. No. 1078874 Make 5/8" E Reading
Name Mr.
No. 24 St. or Ave. THAYER
Location
Date 1-19-31
TEST AFTER REPAIRS
G. P. M. | Percent
PARTS | COST

BRASS
METER REMOVED
Date 4 20 1931 Reg. No. 4-7
Ser. No. 1390353 Make 5/8" T Reading 421300
Name Mr. Charles Remer
No. 1045 St. or Ave. Fayette
Cause
TEST BEFORE REPAIRS
G. P. M. | Percent
Repaired APR 28 1931
Job Order No. 919
Signed

IRON
METER REMOVED
Date 2-3 1930 Reg. No.
Ser. No. 404066 Make 5/8" E Reading 555400
Name Mr. F.F. Fleming
No. St. or Ave. Leet
Cause
TEST BEFORE REPAIRS
G. P. M. | Percent
Scrapped APR 28 1931
Job Order No. 325
Signed

RE METER SET
Date 5/1 1931 Reg. No.
Ser. No. 1390353 Make 5/8" T Reading 421300
Name Mr. Sara Rene
No. 208 St. or Ave. Poplar
Location
Date
TEST AFTER REPAIRS
G. P. M. | Percent
16 | 100
1 | 102
1/4 | OK
PARTS | COST
1- Bottom Cap
1- " " Gasket
1- Measuring Chamber

FIG. 2

Final estimates for payment on contract work are often made up in rather extensive detail, if the contract work was done on a "Unit Price" basis, but where a contract is let on a "Lump Sum" basis the completed quantities may not appear on said "Final Estimate," with the result that such final quantity data may never enter the records, unless some interested, or authorized, person makes the point of having the data so prepared for permanent record. Table 1 contains a part of the data so prepared for work recently completed at Shreveport, La., and it also represents the type of detailed data supporting the summarized figures appearing in table 8.

Many of the larger cities, and utilities, maintain records of cost for water lines, and certain studies are cited here only as examples of

TABLE 6

West Palm Beach Water Company—value of plant and depreciation thereon for May 31, 1927

RATE OF DEPRECIATION		VALUE APRIL 30, 1927	ADDITION MAY 1927	VALUE MAY 31, 1927	DEPRECIATION MAY 1927
per cent					
10	Oil purifier	$735.57		$735.57	$6.13
10	Booth dry feeder	550.00		550.00	4.58
10	Concrete mixer no. 1	999.00		999.00	8.33
10	Smith tilting concrete mixer no. 2	2,850.00		2,850.00	23.75
10	Wonder no. 7 concrete mixer no. 3	1,000.00		1,000.00	8.33
10	2 chlorinators type MSVM	2,624.56		2,624.56	21.87
10	Ingersoll-Rand air compressor no. 1	1,994.17		1,994.17	16.62
10	Ingersoll-Rand air compressor no. 2	1,775.00		1,775.00	14.80
10	Ingersoll-Rand air compressor no. 3	2,900.70		2,900.70	24.17
10	12-inch suction dredge	67,090.98		67,090.98	559.10
10	Barge for dredge	1,501.70		1,501.70	12.51
10	Barge for Lake Worth mains	711.10		711.10	5.93
10	Pontoons	12,879.42		12,879.42	107.33
10	Engineering equipment	632.82		632.82	5.27
10	Drum hoist machine eng. 27900	1,706.90		1,706.90	14.22
10	Fence around pumping station	1,755.44	$94.45	1,849.89	15.42
8	Miscellaneous tool account	3,179.67	86.71	3,266.38	21.78
7	2 Phoenix boilers nos. 1 and 2	5,022.57		5,022.57	—
7	Walsh and Weidner boiler no. 3	8,155.03		8,155.03	47.57
7	Walsh and Weidner boiler no. 4	7,429.53		7,429.53	43.34
5	Meters to 12/31/26	107,294.05	*75.00*	107,219.05	446.75
5	Meters—W.P.B. since 12/31/26	2,127.31	*412.30*	1,715.01	7.14
5	Meters—P.B. since 12/31/26	56.40	15.00	71.40	.30
5	Sewer—Tamarind Street	1,720.59		1,720.59	7.17
5	Waste oil filter	75.00		75.00	.31
5	Feed water heater	100.00		100.00	.42
5	6-inch Lawrence Sturtevant pump	2,011.87		2,011.87	8.38
5	8-inch Lawrence Sturtevant pump	2,409.88		2,409.88	10.04
5	10-inch Lawrence Sturtevant pump	2,948.70		2,948.70	12.29
5	Alum feed machine	1,083.36		1,083.36	4.51
5	Wheeler condenser	5,354.11		5,354.11	22.31
5	3 m.g.l.l. pump and motor no. 1	1,840.40		1,840.40	7.67
5	3 m.g.h.l. pump and motor no. 2	2,835.50		2,835.50	11.81
5	8 m.g.l.l. pump and motor no. 3	4,098.10		4,098.10	17.07
5	6 m.g.h.l. pump and motor no. 4	4,304.12		4,304.12	17.93
5	15 m.g.l.l. pump and motor no. 5	4,472.60		4,472.60	18.64
5	12 m.g.h.l. pump and motor no. 6	7,088.75		7,088.75	29.54
5	Drainage pump and motor	1,337.50		1,337.50	5.57

TABLE 6—*Concluded*

RATE OF DEPRECIATION		VALUE APRIL 30, 1927	ADDITION MAY 1927	VALUE MAY 31, 1927	DEPRECIATION MAY 1927
per cent					
5	Drainage pump and motor	$1,337.50		$1,337.50	$5.57
5	Primer and motor	703.52		703.52	2.93
5	Primer and motor	703.53		703.53	2.93
5	Electric switchboard and wiring from incoming line to switchboard and motors	19,912.70		19,912.70	82.97
5	Galvanized mains W.P.B. since 12/31/26	17,079.25	153.06	17,232.31	71.80
5	Galvanized mains P.B. since 12/31/26	290.66	87.43	378.09	1.58
5	Service lines to 12/31/26	230,008.40	*36.30*	229,972.10	958.22
5	Services W.P.B. since 12/31/26	22,144.97	507.81	22,652.78	94.39
5	Services P.B. since 12/31/26	1,021.50	136.86	1,158.36	4.83
2½	2 m.g. standpipe—Parker Avenue	70,523.85		70,523.85	146.93
2½	Wash water standpipe—Banyan Street	6,648.68		6,648.68	13.85
2½	Oil house	200.00		200.00	.42
2½	Pump house	34,676.24		34,676.24	72.24
2½	Store house	2,917.54		2,917.54	6.08
2½	Lime feed house	105.23		105.23	.22
2½	Chief engineer's cottage	4,939.78		4,939.78	10.29
2½	Second engineer's cottage	518.83		518.83	1.08
2½	20-inch venturi meter no. 8959	1,198.93		1,198.93	2.50
2½	16-inch venturi meter no. 879	1,082.40		1,082.40	2.25
2½	13-inch by 30-inch venturi meter	2,397.43		2,397.43	4.99
2½	Water Tower—Palm Beach	45,244.72		45,244.72	94.26
2½	Garage and meter room	2,793.84		2,793.84	5.82
2½	Garage at plant	14,785.49		14,785.49	30.80

cost-analysis. Table 2, showing the analysis used at Erie, Pa., does not separate any costs for rock, or other special conditions, but it does provide a very excellent separation of cost for various types of material and labor. Table 3, for Kansas City, Mo., does show separate costs for both rock and paving; together with a different and very splendid type of analysis. The results of a study made many years ago, by the writer, from record data of Pittsburgh Water Department, during preparation of a valuation report on the water works property, is shown in table 4, while average costs, by the Pittsburgh Study, arranged in graphical form is presented in figure 1. Needless to say,

TABLE 7

Inventory of office equipment, The J. N. Chester Engineers

	COST	ANNUAL DEPRECIATION		YEAR BOUGHT	TOTAL DEPRECIATION	VALUE JANUARY 1, 1930	1930 DEPRECIATION	VALUE JANUARY 1, 1931
		Percent	Amount					
Stenographers' room:								
1 Paper punching machine	$5.00	3	$0.15	1915	$2.25	$2.75	$0.15	$2.60
1 Paper clipper	2.00	10	.20	1928	.40	1.60	.20	1.40
1 Line-a-time 12 inches, no. 106,189	14.00	5	.70	1923	5.00	9.00	.70	8.30
1 Line-a-time	10.00	5	.50	1923	3.50	6.50	.50	6.00
1 6-Drop annunciator, 401	23.00	5	1.15	1924	7.00	16.00	1.15	14.85
1 Signal system	100.00	10	10.00	1928	20.00	80.00	10.00	70.00
1 U. S. duplicator, 9 inches	33.00	5	1.65	1924	10.00	23.00	1.65	21.35
Total no. 2	$187.00		$14.35		$48.15	$138.85	$14.35	$124.50
Business administration:								
1 Coat costumer	$8.00	3	$0.24	1928	$0.50	$7.50	$0.24	$7.26
1 High bookkeeper desk, 60 by 33	29.00	3	.90	1912	16.00	13.00	.90	12.10
1 Green ash tray	1.00	5	.05	1926	.20	.80	.05	.75
1 Small electric fan	23.15	5	1.15	1918	13.15	10.00	1.15	8.85
1 Small flat desk, 34 by 42	23.50	3	.70	1915	10.50	13.00	.70	12.30
....								
1 Paper clipper	1.00	10	.10	1928	.20	.80	.10	.70
1 Steel lock money box	2.00	5	.10	1920	1.00	1.00	.10	.90
1 Green rug, 4½ by 19 feet	52.00	10	5.20	1922	41.60	10.40	5.20	5.20
1 Glass window guard	5.00	3	.15	1928	.30	4.70	.15	4.55
1 Small taboret	1.00	5	.05	1915	.75	.25	.05	.20
1 All record book	10.00	10	1.00		5.00	5.00	1.00	4.00
Total no. 3	$606.07		$47.29		$340.10	$265.97	$47.29	$218.68

TABLE 8

A comparison of contract costs for various items of filtration plant and pumping station

ITEMS	28 M.G.D. 1927 NASHVILLE, TENN.		20 M.G.D. 1923 WHEELING, W. VA.		VARIED CAPACITY 16 M.G.D. 1930 ERIE, PENNA.		8 M.G.D. 1930 SHREVEPORT, LA.		BIDS 1928 8 M.G.D. 1929 LOCKPORT, N. Y.		3 M.G.D. 1928 BOWLING GREEN, KY.		ZEOLITE SOFTENING 2 M.G.D. 1928 SEWICKLEY, PA.	
	Total	Per million	Total	Per million	Total	Per million	Total	Per million	Total	Per million	Total	Per million	Total	Per million
Coagulating basin:													(a)	
Excavation	$37,420	$1,336	$25,680	$1,284	$37,000	$1,157	$9,359	$1,169	$7,709	$964	$1,600	$533	$922	$461
Concrete	96,153	3,434	118,885	5,944	133,170	4,162	32,514	4,064	50,500	6,312	20,500	6,833	10,414	5,207
Superstructure	1,455	52	16,800	840			15,958	1,995						
Equipment			25,695	1,285 (i)	With piping				6,700	838	8,850	2,950		
Outside piping, etc.:	59,861	2,138	59,523	2,976	92,000	2,875	35,731	4,467	64,500	8,063	15,200	5,067	7,660	3,830
Filter building and pumping station:	(b)		(b)		(d)(e)		(b)				(c)		(c)	
Excavation	19,800	707	11,420	571	16,000	250	2,608	326	4,060	508	7,200	2,400	7,808	3,904
Concrete	85,800	3,064	108,482	3,424	88,112	1,377	11,941	1,493	40,000	5,000	20,700	6,900	31,132	15,566
Superstructure	110,400	3,943	105,945	5,298	208,000	3,250	9,166	1,146	67,000	8,375	39,000	13,000	39,300	19,650
Heating	9,800	350	2,800	140	16,000	250	510	64	6,839	855	2,200	733	4,900	2,450
Plumbing	6,500	232			4,800	75			2,740	342	900	300	1,300	650
Electric wiring	4,263	152	5,000	250	4,800	75	210	26	5,288	661	2,000	667	2,200	1,100
Elevator	5,700	204	5,780	289	5,500	86			3,750	469	3,600	1,200	3,500	1,750
Crane					8,320	130			1,850	231	1,600	533	2,300	1,150
Hoist	2,000	71									1,350	450		
Conveying equipment			9,498	475							1,350	450		
Filter plant equipment:														
Filter piping	66,000	2,357	32,500	1,625	50,246	2,100	17,040	2,130	15,780	1,973	13,500	4,500	8,450	2,225
Filter strainers			14,500	725					4,800	600				
Operating tables	7,000	250	5,000	250	5,770	361	2,366	296	3,900	488	2,550	850	3,075	1,538
Rate controllers	16,300	579	11,760	588	10,195	637	4,629	579	5,900	738	4,000	1,333	2,575	1,288
Master controller	2,200	79	2,250	113					2,360	295	750±	250		
Filter sand and gravel	13,000	464	11,650	583	10,650	666	3,743	468	5,275	660	650	217	10,070	5,035
Wash troughs	5,400	193	4,000	200	2,950	184	1,428	179	2,192	274	1,050	350	625	313
Wash water controller	4,000	143	3,070	154	650	41					1,000	333	565	286
Dry feed machine	3,300	118	6,600	330	5,500	175	1,800	225	2,715	340	1,800	600	475	238
Mixing equipment	8,485	303	With settling		7,585	237	1,253	157	5,850	731	2,400	800		
Chlorine equipment	4,800	171	3,500	175	4,290	134	2,610	326	2,850	356	3,500	1,167		
Venturi or flow meter	3,800	136	3,000	150	7,320	305	1,295	162	2,600	325	1,500	500	800	

Wash water tank...................			11,924	596			4,850	606	2,150	269(h)				
Pumping equipment:														
Low service pumps............			23,330	1,167 (f)	12,935	809	4,560	570	16,600	2,075	2,895	965	1,610	805
High service pumps...........			51,600	2,580 (f)	16,650	1,041	7,469	934	19,200	2,400	4,035	1,345	4,115	2,058
Condenser.....................			7,050	353										
Vacuum pump.................			1,245	62	1,010	63			425	53	355	118	350	175
Wash water pump..............			3,945	197	550	35			730	91			1,006	503
Power wiring and equipment			With pumps		43,000	1,800± (g)	17,338	2,167			5,000	1,667	4,050	2,025
Pump piping..................			33,149	1,658	52,316	1,323(g)	6,641	830	4,000	500			2,870	1,435

(a) Equalizing chamber and brine tank only. (b) Filter building only,—(with clear well and pumping station elsewhere, for Shreveport) but with clear well underneath for Nashville and Wheeling. (c) Including low service pump pit to river level. (d) Under construction and figures are tentative. (e) Certain items carry capacity for extension. (f) Including power wiring and electric equipment. (g) Separate pumping station for high and low service. (h) Exclusive of tower. (i) Including mixing equipment.

all of the foregoing samples are supported by very complete detail data.

Table 5 represents the method employed at one time for Washington, Pa., in separating the costs for service lines to labor, materials and repaving charges, whereas many companies use a card system for recording the data on costs and materials, for each service line, together with a sketch showing exact location, length, and position of curb box, in relation to visible street or property lines. Such a card system offers an excellent method for a "Perpetual Inventory" of service lines; combined with the permanent records of location, extent and cost analysis.

Figure 2 pictures the type of meter records now employed at Washington, Pa., for the permanent history of each meter in service. This type of record card also provides a perpetual inventory for meters-in-service, to which may be added such other information and cost data as may be desirable.

Excellent samples of the card system are in use at Erie, Pa., for "Perpetual Inventory" of Property Account and the beauty of this system is the ease with which it can be expanded and detailed to meet any individual desire, or idea. These cards also carry the record depreciation for each and every item of Property Account.

Table 6 shows the result of continuous Property Account, or Perpetual Inventory, for the West Palm Beach Water Company, together with the method of current depreciation for each and every property item.

A sample listing from the Perpetual Inventory for Office and Field Equipment of The J. N. Chester Engineers, together with the method of charge to depreciation reserve, is shown in table 7. This last method is employed to meet the specific local conditions, and would not be applicable in full, for utility records, but it does represent an accurate and satisfactory method of solving a detail problem.

Table 8 presents a comparison of costs, summarized from such sources as represented by table 1 and for those certain items of plant encountered, in the construction of water purification plants, with pump station; ranging in capacity from 28 million gallons daily, at Nashville, Tenn., to 2 million gallons daily for the zeolite softening, at Sewickley, Pa. Varied capacities, however, are represented in the cost figures for the Erie plant, ranging up to a 64 m.g.d. rated capacity now provided in the high service pumping station structure and coagulant house, sufficient for ultimate extension of filters for this unit.

A fair comparison is possible for items, or groups of equipment, not greatly affected by labor rates, but the wide spread in labor rates from the North to the South prevents a true comparison between those structures requiring a large amount of common labor for their completion. For instance, the cost for item of Filter Gallery Piping may be only slightly affected by the local common labor rate, whereas the cost for items of concrete and excavation may be greatly influenced thereby.

No attempt is made to draw conclusions from these sample data. They are offered only as an accelerator to further discussion of these related features.

I well realize, with you, that certain water works records have been kept in most excellent condition, from the beginning, but I am also of the opinion that a clear vision in the recording of plant items will even further improve the good records and would completely revolutionize those records which have been neglected in this regard.

In closing, I might venture the thought that the adoption and maintenance of a "Perpetual Inventory" would furnish the vehicle for more and better cost analysis and, secondly, that the card system offers the most practical and flexible system for the maintenance of a "Perpetual Inventory;" including all divisions of the "Property Record."

DEPRECIATION ALLOWANCE FOR FEDERAL INCOME TAXES

By Louis D. Blum[1]

One of the most important as well as vexatious questions confronting accounting officers of water companies today is that of depreciation. This question has always been of paramount importance from the standpoint of invested capital, earnings and rates, but only recently, because of the activities of the Treasury Department, has it become of importance from a standpoint of taxation.

The old haphazard manner of calculating a flat rate of four or five per centum on a mixed aggregate of unclassified assets will no longer be permitted for use as a deduction from income for tax purposes. The taxpayer must now be able to show the kind of property, date of acquisition, its estimated life, the depreciation taken in previous years and the amount of reserves for depreciation against the assets on which depreciation is claimed. Moreover, the depreciation claimed in the tax return, as well as the reserves therefor, should be set up on the general books of account or subsidiary records in sufficient detail to enable the department to verify the correctness of the amount of depreciation claimed.

Now just what is depreciation? Depreciation is that loss of value whether tangible or intangible in form, resulting from physical decay, obsolescence and inadequacy. It necessitates repairs, renewals and replacements and were it not for depreciation, expenditures of every character relating to plant property would add to the investment in such property.

Because depreciation results from so many diverse causes it has given rise to the belief that it cannot be scientifically provided for and one frequently hears the remark that since all estimates of depreciation are merely guesswork, one person's guess is as good as another's.

It is quite true that differences in depreciation occur not only in unlike properties, but also in those of identical construction. One

[1] Certified Public Accountant, New York, N. Y.

thing may be so constructed that under ordinary usage it wears slowly and it may become obsolete long before it wears out. Another may wear out rapidly with no chance of becoming obsolete and a third may become totally inadequate to perform the service for which it was intended long before it either wears out or becomes obsolete.

Any consideration of depreciation must therefore embrace obsolescence and inadequacy as well as actual physical decay or wear and tear.

Depreciation calculations for purposes of capitalization or for use in valuations for rate making should not be confused with calculations made for purposes of taxation as the two purposes are entirely dissimilar. In the first the object is to find the value of a thing at a particular date, while in the second the object is to provide a reserve fund sufficient to care for the replacement of assets as they become useless or worn out. This difference has been recognized by the United States Supreme Court and it has held that the physical valuation of property used for taxation purposes could not be used for purposes of rate making because the basis of such valuation was too narrow to comprehend all the elements of value.

The Bureau of Internal Revenue of the Treasury Department has through its engineering section made a comprehensive study of the question of depreciation as related to various industries and in a booklet entitled "Depreciation Studies," January, 1931, has outlined a tentative schedule of rates. In most cases the rates suggested appear to be fair and reasonable, although they should be weighed in the light of individual experience and adjusted to meet the situation as presented by the facts in individual cases.

With the Bureau's study of depreciation rates as well as other available information on the subject, it is a comparatively simple matter to arrive at satisfactory rates, although far more difficult to reach a satisfactory basis.

The segregation of assets into proper groups, in modern accounting practice, is a comparatively recent development and cannot be traced farther back than the promulgation of the first income tax laws. For this reason it is often difficult and at times impossible to properly segregate a mixed aggregate of unclassified assets appearing in the books of account at an early date.

At first it would seem that the Department is unreasonable in demanding the segregation of assets for purposes of depreciation, but

it should be borne in mind that the taxpayer must be in a position to prove the deductions claimed. Under the circumstances, therefore, it is only fair for the Department to ask for information which will enable it to determine the reasonableness of the depreciation deduction.

My experience in the handling of nearly two hundred cases before the Treasury Department, more than half of which involved the question of depreciation with respect to water utilities, leads me to the conclusion that the Department is fully alive to the difficulties to be overcome and is just as desirous of working out a satisfactory basis as the taxpayer and that the government's representatives are without exception, men of character and ability who painstakingly consider all of the claims put forth by taxpayers, especially when such claims are properly presented.

In nearly all water plants built more than 25 years ago and in many built during the past 25 years, if one goes far enough back into the records, a single ledger account is usually found representing the entire plant. This account may represent depreciable as well as non-depreciable assets and even among those assets usually considered depreciable may be found items of a non-depreciable character. Heretofore the Bureau of Internal Revenue has held that since expenditures during construction, such as engineering and superintendence, injuries and damages and insurance, could not be properly assigned to the cost of specific units of physical property, no depreciation would be allowed with respect to such expenditures. The U. S. Board of Tax Appeals decision in the Paducah Water Company case has been cited and relied upon in support of this position.

Within the past thirty days, however, the General Counsel of the Bureau of Internal Revenue has issued a memorandum to the effect that the decision in the case of the Paducah Water Company revolved on the fact that the items in question were not actual cash expenditures, but intangible or estimated items arising from an appraisal. He goes on to say that "where a given capital expenditure of a more or less general nature can reasonably be said to have entered into the cost of several depreciating properties, but cannot be specifically attributed to particular properties, it would appear that the requirement of the statute and regulations would be met by an apportionment process which would divide the expenditure among the several properties benefited."

With respect to the question of whether a given expenditure entered

into the cost of depreciating property, the General Counsel states further that "it would appear generally that if an expenditure was of such a nature that it would recur with each reconstruction of a plant or property, then that expenditure may reasonably be said to constitute a part of the cost of the property for depreciation purposes."

In accordance with this opinion of the General Counsel, it would appear that expenditures of a general nature arising during construction may be included in the cost of the property to be depreciated.

It is needless to say that such items as good-will, perpetual franchises and like assets of an intangible character are non-depreciable and no depreciation will be allowed on such assets by the Department for purposes of taxation.

In cases where it is impossible for the taxpayer to properly segregate a mixed aggregate of unclassified assets, one usually finds the Department willing to aid him in every possible way, provided the subject matter is presented in a comprehensive and intelligent manner and gives evidence of conscientious effort on the part of the taxpayer to arrive at a satisfactory basis for purposes of depreciation.

In all of my cases before the Department involving questions of depreciation of water utilities I have invariably made a complete analysis of the fixed assets as far back as the books of account would permit and have eliminated all non-depreciable assets. Assets abandoned, replaced, or worn out, as well as those fully depreciated are charged to the proper reserves for depreciation. Depreciation is charged and the reserve account credited with depreciation at established rates, from the date the property was acquired to the present time and all property fully depreciated is excluded at the end of its estimated life.

The rates used, while not exactly in conformity with those suggested by the Treasury Department, are intended to comprehend functional as well as actual depreciation, the factor of inadequacy being fully considered in arriving at the rates.

In utility accounting the classification of property usually does not disclose the acquisition or installation date of a particular asset, but the accounts show the property by classes and the additions during a particular year may be ascertained by reference to the plant ledger or other auxiliary record. For the reason that the computation of depreciation on each addition to plant would not be practicable, such assets as distribution mains, transmission mains, hydrants, services, meters, etc. are grouped. The rates of depreciation applied to these groups are therefore in reality composite.

The use of a composite rate of depreciation for the entire plant would, under the present procedure of the Treasury Department, make it impossible to obtain a deduction because of the abandonment or premature retirement of property. The position of the Department is based on the inability of the taxpayer to ascertain the exact date of installation and correct amount of depreciation sustained on the

TABLE 1

Depreciation allowances suggested by United States Treasury Department

	PERCENT OF DEPRECIATION
Buildings	2 to 3
Cribs:	
Concrete	2
Timber	4
Filters:	
Pressure type (steel)	4
Slow sand-gravity type	2
Hydrants:	
Less than 6 inches	3
6 inches and over	2
Pipes:	
Cast iron:	
8 inches and larger	$1\frac{1}{3}$
Less than 8 inches	2
Concrete or masonry	2
Wrought iron and steel:	
Less than 6 inches	$4\frac{1}{2}$
6 inches and larger	3
Reservoirs	$1\frac{1}{3}$
Services (galvanized)	3
Tanks and standpipes:	
Concrete	2
Steel	$3\frac{1}{3}$
Wood	5
Water-treatment equipment	10

property abandoned or retired. In connection with the use of a composite rate of depreciation on unclassified property, the various classes of which depreciate at different rates, the Treasury Department contends that inasmuch as some property is depreciated after its useful life has ended, this allowance would offset any claim for loss on property abandoned.

With respect to the adoption of rates, I might say that uniform

rates cannot be applied to all properties. Full consideration should be given to the accounting procedure, maintenance policy, kind of construction, size of mains, soil conditions, characteristics of the water which may cause mains to corrode quickly, fire protection, population and its expected increase, shifts of consumers to different districts, etc. After these facts are ascertained the rates fixed should provide for the retirement of the plant as a result of wear and tear and inadequacy.

The rates suggested by the Treasury Department are shown in table 1.

It should be borne in mind that the Treasury Department does not prescribe the foregoing rates as standard, as this would only be possible if standard methods of operation and accounting existed.

It is impossible in the time to which a paper of this kind must be limited, to go into all of the many phases of a matter so complex as that of depreciation, although it is my desire to be helpful, and if my very brief discussion of the subject from a tax accounting standpoint will only result in more careful consideration of the matter of depreciation, I shall feel that I have accomplished a service to our organization.

MARKETING PUBLIC UTILITY SECURITIES

By H. Gordon Calder[1]

Marketing Public Utility Securities is a subject on which volumes could be written and discussion held for months without covering all of the matter which the title suggests. However, a brief outline of the manner in which those responsible for financing utilities, either municipally or privately owned, may analyze the problem of financing and finding a market for the securities which may be issued in connection with financing, should be of interest to all connected either directly or indirectly with public utility management. No one will find any miraculous cure for financial ills in these lines or anything suggesting that a new Ponzi has appeared on the business horizon, but the application of this outline to a particular and local problem should at least help the management to arrive at a starting point for some definite solution of that problem.

TYPES OF FINANCING

There are essentially two kinds of financing—temporary and permanent. The municipally owned utility may use warrants, funds of other departments, derived from taxation, or in some cases bank loans as temporary measures of obtaining money. Private companies may use bank loans, short term gold notes of a more formal character, debentures which are callable, or the forced expedient of passing dividends. Either municipality or private company may secure special terms from creditors to tide them over short periods of time.

Financing of a permanent nature may take the form with the municipally owned utility of bonds of either the municipality or the utility department (providing that department has been properly divorced from the balance of the municipality), or by the sale of the plant to private enterprise where the municipality finds that its own financing has reached a stage where the sale of the property is cheaper to the tax payer than continued operation. The municipality may also join with other towns or villages in the creation of a special district

[1] International Public Service Corporation, New York, N. Y.

for the purpose of financing and administering the utility in question. An examination of the State laws will disclose the possibilities and limitations of this method.

The private company has at its disposal a greater variety of methods for permanent financing. It may sell bonds, with either first or second mortgages on the plant, and/or some form of debentures with a mortgage only on earnings. They may either in connection with the sale of bonds or preferred stock give options to buy common stock of the company as an additional inducement to buy the senior security. It may sell preferred stock which may be preferred as to dividends only, or preferred as to dividends and assets, or which is preferred as to a limited portion of the dividend and which shares with the common in earnings in excess of the limited dividend. The preferred may be either voting or non-voting, and if one class of preferred has been issued another class junior to the first but senior to the common stock may be issued. Lastly it may issue one or more classes of common stock. The Company may issue a common stock which is preferred as to a portion of the earnings—with or without voting privileges, or it may issue common stock all of one class which has no special rights. Finally the smaller local private company as in the case of the municipality may find it advantageous under some circumstances either to sell or merge with a larger group so as to secure the strength of their credit.

Public Service Commissions and Blue Sky Commissions requirements and laws should be carefully checked in connection with the issuance of any securities.

ANALYSIS OF FINANCIAL PROBLEM

In deciding whether the financing will be temporary or permanent and the kind or kinds of securities or means to be used in securing the required money, the following outline may be used in analyzing the financial situation of the department or company, and, if the questions raised are carefully studied and answered, the management may feel that the major factors have been given proper consideration. Careful cash budgets as to the immediate and future requirements should be prepared. Supporting these cash budgets should be operating budgets, which, of course, will tie in closely to the cash situation. Construction budgets should be prepared, with the major construction requirements listed separately. At least twelve months ahead should be scheduled, with separate figures for each month, and a total

for the year on each item in the budget. Further, in working out any financial scheme, the yearly requirements should be projected ahead at least 5 years, and some thought should be taken as to what the plant and its requirements will be 25 years ahead, because any plan for the development or financing of a utility must give proper weight and consideration to the growth of the community and necessity for the extension of services, additional water supplies, and replacements. In connection with this idea of preparing for the future, if sinking fund bonds are issued, it will frequently be found that not only is it difficult to find the funds for the sinking fund requirements, but that additional capital will be needed in future years which will not permit the retirement of present financing. Foresighted private utilities usually solve this problem by issuing bonds under mortgages which permit the pledging of additional construction as security for additional bonds to be issued at a later date, and preferred stock or common stock is usually authorized in the charter in excess of the immediate requirements and under provisions which permit additional issues as the physical plant and earnings warrant.

A careful examination of the net earnings available for interest or dividend requirements should be made, and in considering the issuance of new securities the relationship of the amount required for bond interest or dividends to the net earnings available for that purpose should be considered. This is frequently one of the principal factors in determining the price at which the securities may be sold.

The physical assets which are available for pledging under mortgage should be considered and careful statements prepared showing the book value of such assets as well as their appraised valuation.

MARKETS

Market conditions must be taken into account and viewed from at least three angles. The security selected should be the one best adapted to the demand in the then present market, that is, if bonds are bringing a better price than preferred, all other factors being equal, bonds should be selected. Second, the kind of security should be selected which is best adapted to the market in which the security is to be sold. That is, experience has shown that in selling securities to consumers some kind of preference stock usually moves better than any class of bond. However, a few wealthy consumers might be found to purchase an entire bond issue if not too large. The foresighted utility will do well to consider its future money re-

quirements when the market is in good condition to receive securities so that it may secure the most advantageous rates.

In the municipality as well as in the private company, the management will do well to consider the local political conditions which might affect adversely the kind of financing planned. There are unquestionably other factors which might affect the financial plans of the utility. They cannot all be covered here.

Where are the markets? The principal ones are listed as follows: local bankers and brokers, customers, outside markets as represented by bankers and investment bankers with state and national distributing facilities. The local banker should be of great assistance to the local utility operator in finding a market for his securities, but it is unfortunately necessary for the management sometimes to look farther. In connection with large issues it is frequently easier to sell the securities through a New York banking investment house. In connection with small municipal issues, it is sometimes difficult to interest the large investment banker. There are, however, investment bankers and houses who specialize in small issues. A list of these is not difficult to obtain. In actually selling the security, the price may be influenced by many factors, among which are: The past reputation of the utility or municipality asking for money; the physical property which will represent the security for the money and its condition; the earnings available for the payment of the interest or dividend requirement as represented by the money asked for, and, last but not least, the availability of accurate records and information supporting any or all of the information required by the house with whom negotiations are being carried on.

RECORDS

The records kept by the utility become then of the utmost importance. They are no longer a mere bookkeeping record of what was received and what was spent, but may represent the basis on which the rate charged for the money will be determined. Good utility management will, therefore, keep at all times a complete and accurate record of earnings and will build up historical information of past years' earnings so as to show the trend of the business, and will keep a complete record of construction costs and investment in plant and property, together with a record of property abandoned or removed so that it is always available for the purpose of financing as well as that of management control. Any potential purchaser of a utility

security, if he is intelligent, is interested not only in the financial and historical record of the utility itself, but he is interested in the growth of the community, the kind of industries located in that community, the number of schools and the surrounding territory on which the community's prosperity may be based. That kind of information should always be available when the utility goes to market.

PUBLICITY

Good utility management will bear in mind that it is easier to sell something known than something unknown. Who would have bought airplane securities 30 years ago? The management will therefore not neglect any opportunity to secure publicity, both locally and nationally, of the right sort. After securities have been placed in the hands of investors the management should keep those investors informed at all times of the condition and progress and earnings of the plant which represents those investors' money. If the bonds have been sold through a New York house regular information should be sent to that house for release to the New York newspapers and for broadcasting to the newspapers in the communities where those securities may have been sold.

Lastly, intelligent investors look to the management of the business in which they place their money for the safety of that money and the assurance of a return on it. Therefore the management must preserve at all times its integrity and reputation for honest, intelligent, and efficient operation. Nor will any intelligent buyer purchase a horse which the owner obviously wants to sell. The management of the utility must, therefore, at all times believe in its business and must optimistically present its story at every opportunity.

SUB-AQUEOUS PIPE LINES

A. T. RICKETTS:[1] Sub-aqueous pipe lines include pipe lines laid through or under any body of water. It is assumed, however, that those lines which are lowered through the water in the operation of placing and usually require special joints for their installation, will be of most interest.

This is a subject of considerable importance indeed to many superintendents because of the relatively high installation cost of sub-aqueous lines and because when trouble does occur after the lines have been put in service, it is usually persistent and the source of large increases in the maintenance charges. In addition to the high installation and maintenance charges, sub-aqueous pipe lines are often a source of leakage materially affecting the operating costs. Such losses if gradually developed may become quite large and continue for many years without detection. Any information that the individual can furnish which will in any way improve construction methods or suggest ways for the solution of problems of this kind, will naturally be helpful.

The speaker would like to submit a brief description of a sub-aqueous pipe line just completed for the Charleston Plant of the West Virginia Water Service Company.

24-INCH PIPE LINE CROSSING OF THE KANAWHA RIVER AT CHARLESTON, WEST VIRGINIA

Before describing the pipe line, it will be of interest to review briefly the conditions necessitating its installation. The Charleston Plant of the West Virginia Water Service Company takes its supply from the Elk River at the northerly boundary of the community and heretofore has been supplied from the flow of this stream above the intake. During the extreme drought recently experienced, this flow became less than the quantity pumped creating a back flow in the river from its confluence with the Kanawha about 1600 feet below the water works intake. The Kanawha River water is acceptable

[1] Deputy Chief Engineer, Trojan Engineering Corporation, New York, N. Y.

for a domestic supply, but due to the location of the water works intake, the water drawn thereto was polluted by the discharge of Charleston sewers. Numerous schemes were considered to meet the emergency, but it was finally decided that a pumping station located on the southerly bank of the Kanawha where water free from sewage pollution could be obtained, would be the most economical emergency solution of the problem. This location of the pumping station necessitated the laying of about 825 feet of 24-inch sub-aqueous pipe line. After the necessity for emergency pumping has passed, it is proposed to use this pipe line to interconnect the distribution systems across the Kanawha.

Because of the ease of laying and quick delivery which could be obtained, Universal pipe was selected. This is the first time pipe of this pattern, 24-inch in diameter, has been used for this purpose. The profile of the stream bed on the proposed line of pipe is fairly uniform and on a slight curve. The maximum depth of water is about 17 feet for normal stages and, at this point, the river bed is rock. Requirements of the War Department were for a clearance of 14 feet which did not necessitate excavating the rock. Each side of the rock bottom and where depth of overlying material permitted, a trench 3 feet deep was dredged. This was done very carefully to provide a concave bed for the pipe line.

Eight pieces of pipe 4 feet long or a total length of 32 feet were bolted together on the deck of a barge to conform to the profile of the trench. This section was then bolted to a 12-inch I-beam on which inverted wooden cradles were fastened to conform to the curve of the pipe section. The straps holding the pipe were so arranged as to permit an easy release by the diver. The entire section was then lowered by a floating derrick to its position in the line. After the section was bolted to the previously laid pipe, it was held in position by the derrick until the diver jetted enough backfill under the pipe to give it a good earth bed for its entire length. No blocking was used in order to give free movement to the individual pipes in case of unequal settlement. After the section was thoroughly bedded, the I-beam with the cradles was released by the diver and used for the following section.

Sufficient sand was found on the rock bed to cushion the pipe. The current in this section of the river is not at any time very swift, but in order to prevent drifting, the pipe line was supported by dowels placed in the rock along the downstream side of the pipe.

Holes 2 feet deep were drilled in the rock with ordinary air drilling equipment by the diver, one for each section of the pipe and the 2-inch dowels were dropped into these holes. After the dowels were placed, bags of premixed concrete were jammed between the dowel and the pipe so as to form a smooth cradle.

The specifications called for leakage in the sub-aqueous line not to exceed 200 g.p.d. per inch mile of pipe. This is equivalent to about 3.6 gallons per joint. The first test was made after 288 feet of pipe had been laid and amounted to 1,245 g.p.d. per inch mile. There were no repairs made at that time and the leakage did not increase for the balance of the 825 feet. Before the line was completed, the leakage actually took up in the first sections laid as indicated by periodic sectional tests and reduced to about 300 g.p.d. per inch mile. After the line was completed, the section which leaked badly at first was gone over and the leakage was easily reduced to approximately 42 g.p.d. per inch mile. The preliminary tests were made by pumping from a calibrated barrel. The final test was made through a tested meter connected to a City fire hydrant. The pressure thus supplied was slightly under the pressure specified for test, but it was thought to be entirely satisfactory due to the small leakage obtained. The laying of the 825 feet of sub-aqueous pipe was done by Merritt, Chapman and Scott and accomplished in less than thirty working days from the time the dredging was started until pipe line was tested. It cost about $18 per foot including engineering.

The Universal pipe furnished had only two lugs. The experience in laying this line would indicate that this type of pipe, as large as 24-inch in diameter, should be provided with additional lugs. No actual difficulty was experienced, but the possibility of failure of the line due to the breaking of a lug is such as to warrant the additional safeguard.

There is nothing of especial interest in the laying of the sub-aqueous line above described, except that it is the largest diameter line of this type and because it illustrates a manner in which an emergency of this kind was met. For these reasons it is hoped the description will be of interest.

MYSTIC RIVER CROSSING

H. L. CLARK:[2] The Mystic Valley Water Company serves Mystic and Stonington, Connecticut.

[2] Engineer, U. S. Engineering Corporation, New York.

Mystic lies partly in Groton and partly in Stonington. The boundary line between these towns is the Mystic River. The settlement of Mystic has grown up on both sides of the river oblivious of political boundaries. The main street of Mystic forms part of U. S. Route No. 1, which carries the main automobile traffic from New York to Providence, Boston and points on the Cape. This route crosses the Mystic River on a draw bridge.

The water company followed the main street in laying out the distribution system and the original river crossing was laid in 1888 with 12-inch ball and socket joint cast iron pipe. The pipe was made up on the shore and pulled into place by a capstan which was operated by a yoke of oxen. The original crossing gave excellent service until 1922. When the present bridge was constructed across the Mystic River it was necessary to remove the pipe line in order to build the piers and abutments. The only failure of this pipe was caused by a crack in one section of the pipe. Bands were fitted around the pipe to prevent further cracking, soft pine wedges were driven into the crack and the bands tightened. This repair job gave service for approximately 15 years and was found to be in good condition when the pipe line was removed.

When the bridge was rebuilt in 1922, a new line of 12-inch Universal pipe was laid. Openings for the pipe were left in the abutments and the piers constructed in the form of an inverted U. The entire line was laid without proper support and due to its faulty construction was a constant source of trouble. It was practically suspended in the mud bottom and consequently an enormous strain was exerted on the bolts and joints. In an effort to provide support, a large number of sand bags were placed under the pipe. These did not serve the purpose and leaks continued to develop. The river is subject to severe tide currents and the pipe was hanging on the abutments with no other support in its 220 feet span. Leakage to the amount of 700,000 gallons per twenty-four hours had developed. An examination of existing conditions was made by a diver and by Mr. Walter H. Chase. This examination indicated that proper support should be furnished to keep the line in operation.

The following method was used in replacing the river crossing: A grade line from each abutment opening to the edge of the channel was established. The original plan was to remove and replace the broken sections of pipe, but when some of these sections had been removed, it was found that the pipe had deteriorated due to

electrolytic action to such an extent that it was not fit for further use. The entire line was therefore removed and replaced by a new line of 12-inch Universal cast iron pipe joined with rustless steel bolts. This line was laid on piling. The piles were jetted or jacked 4 feet into hard bottom along the center line and headers were set at the proper grade. These piles were 8 inch by 8 inch yellow pine, previously treated with red copper paint. As the entire line was under the draw bridge, it was very difficult to drive them to the required depth. After the piles were driven, the War Department insisted that the new line of pipe be laid 3 feet below the former grade in the section under the draw span as further dredging of the channel is contemplated. This greatly increased the difficulty and expense of the work as the preliminary examination had shown that there was no reason to expect any undue difficulties in the construction of the supports. The work of excavating this additional 3 feet had to be done with a sand sucker as it was impossible to use bucket type dredge under the draw bridge. The additional 3 feet carried the grade below the former bridge foundation and made it necessary to pull out old steel sheeting, to cut a channel through two old masonry piers and to remove all of the old sand bags that had been placed under the pipe, as these prevented the sand sucker from working. All of this work was done by divers.

After this work was completed, the 8 inch by 8 inch headers were set to grade and bolted to the piles. The 4 inch by 6 inch cross members, the 4 inch by 6 inch stringers and the pipe were bolted together on the scow and lowered in sections with six or seven lengths of Universal pipe to the section. The job was carried out in the winter months in order to avoid continual interruptions by the opening of the draw span. The weather was extremely cold and the tide ran fast which added to the difficulties of the work.

The two ends of the line were picked up at the abutments on lead sleeves and the test showed small leads at several of the joints. This leakage was corrected by a slight tightening up of the bolts.

Elliott & Watrous, of Mystic, carried out the work under the inspection of the water company's representatives.

Shortly after the river crossing was completed, a leak developed between the abutment and the first manhole. This was traced to a joint located in the center of the Mystic side of the abutment. When the bridge was constructed, the fill back of the abutment was made by using all of the debris that had been left over from the construction

work. This section of the pipe was below low water and it was necessary to use the divers for the repair. In order to facilitate future repairs a tunnel was installed which consisted of a corrugated iron casing surrounded by concrete through which 12-inch line was completed from the river side of the abutment to the first manhole. The whole crossing was then subjected to a test of 150 pounds per square inch with satisfactory results.

Chairman S. H. Taylor: There are two islands in the river between New Bedford and Fairhaven. A bridge crossing both islands connects New Bedford with Fairhaven, and there is a draw crossing the channel between the islands which necessitates a submarine pipe to supply the further island. We have had all sorts of trouble with that. We tried first the 2-inch lead pipe as there are only a few buildings on this island and a 2-inch pipe would have supplied ample water for domestic supply.

The 2-inch lead pipe was originally laid from a lighter and simply dropped on the river bottom without any covering. As you know salt water freezes at 29° and fresh water at 32°, and as a result the lead pipe frequently froze and burst. This line was finally abandoned and later a 6-inch cast iron pipe was laid in a trench dredged to 4 feet below the river bottom. That gave good satisfaction.

Now it has been decided to deepen the channel 5 feet which will expose the pipe to damage mechanically and by freezing. We are now laying a new 8-inch line in a slightly different location 5 feet below the new river bottom, which we expect to have in service before the present 6-inch line is disturbed by dredging operations.

We are using mostly ordinary bell and spigot pipe and special castings with occasionally "Metropolitan" flexible joints to take care of irregularities in the grades and angles. This is being laid from a lighter, three 18-foot lengths being put together on the deck and lowered to the bottom where the joint is made by a diver using the regular braided jute packing and lead wool. This is about the same method that was followed in laying the 6-inch cast iron pipe a few years ago.

Incidentally, it is a very poor investment from a financial point of view, as it cost a few years ago about $16,000, and will cost nearly the same this year, just to supply a few buildings that return a revenue of about $150 a year.

MAKING WATER WORKS STRUCTURES ATTRACTIVE

GEORGE T. HORTON:[1] I am not prepared to say what is, or what is not, attractive but for many years as builders of water tanks we occasionally have met the criticism that water tanks are ugly structures. About a year ago I met a customer and his architect. I told the architect that we could make a tank look just as he wished it to appear. He admitted that he did not know exactly what he desired, suggesting a competition open to the world. We sponsored such a competition and to my surprise there were one hundred and fifty-two designs submitted.

These designs took many forms. Some of them are good and some not so good. Some are almost freakish. I have selected a few that I thought you might like to see.

Figure 1 was awarded first prize. The jury thought it was quite outstanding. It is different and practical. It is not the usual type that we have been building, which brings up the question of whether it is really better, or not.

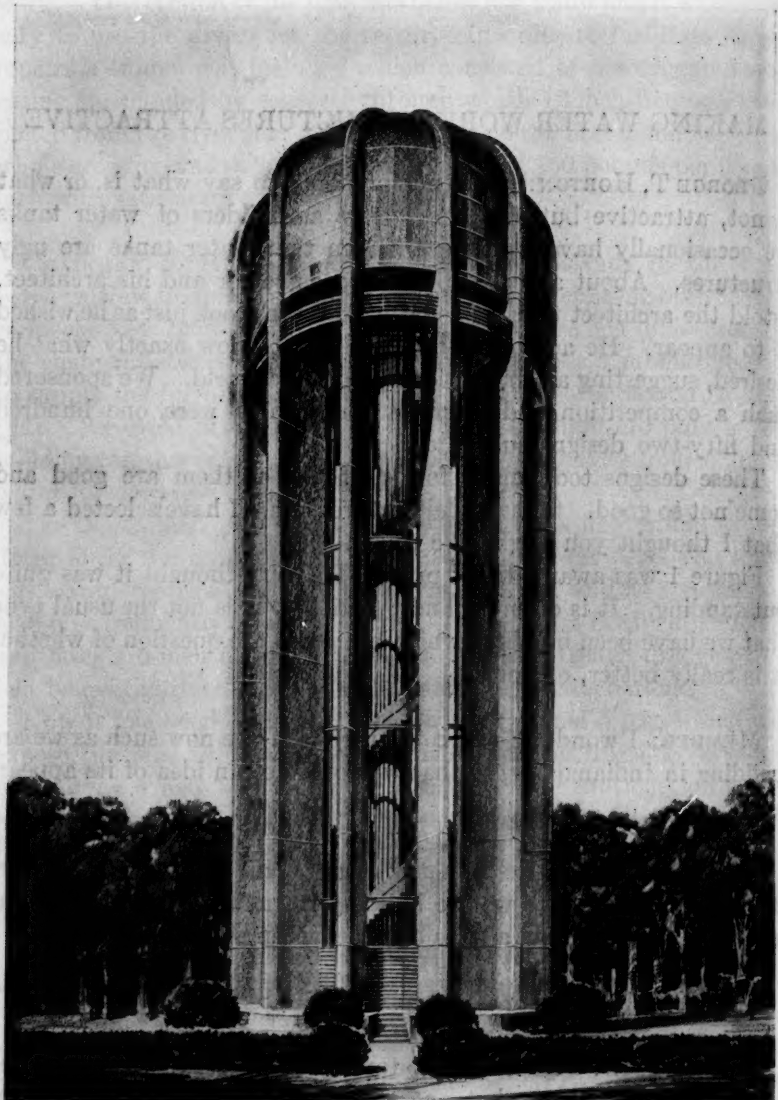
MEMBER: I wonder if you could throw on one now such as we are building in Indianapolis, so that we could get an idea of its appearance.

MR. HORTON: Yes, that is a point that I want to bring out. Figure 2 is similar to the one we are building in Indianapolis, except that at Indianapolis we have a little better eave on the dome roof.

MEMBER: What color is the top of the tank?

MR. HORTON: Figure 2 is a tank at Sandusky. It is painted black, and illustrates that one thing we can do to improve the appearance of any water tank is to paint a brighter color. If some of the simplest structures we are building are painted a bright color they look very well.

[1] Chicago Bridge and Iron Works, Chicago, Ill.



Eugene Voita

FIG. 1. DESIGN WHICH WAS AWARDED FIRST PRIZE IN A WORLD-WIDE ELEVATED TANK COMPETITION SPONSORED BY THE CHICAGO BRIDGE AND IRON WORKS

In the Competition there must have been ten, or fifteen, entrants who seemed to think that urn types of some kind are attractive. One of them, probably the simplest one, is shown in figure 4. It is very

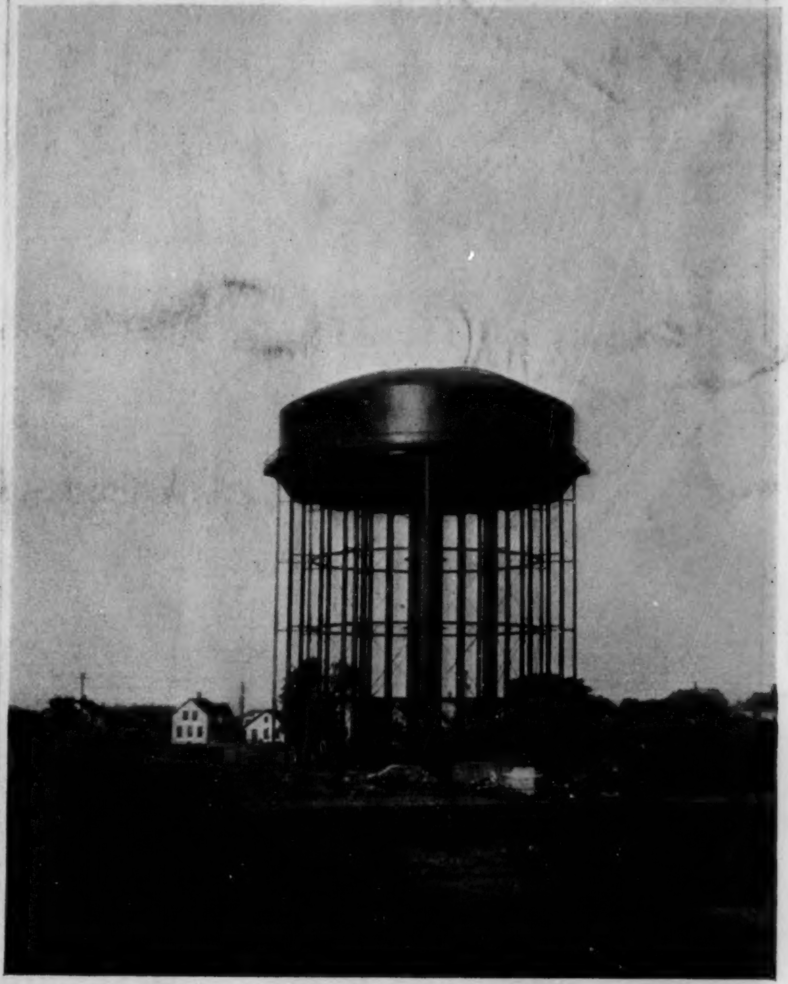
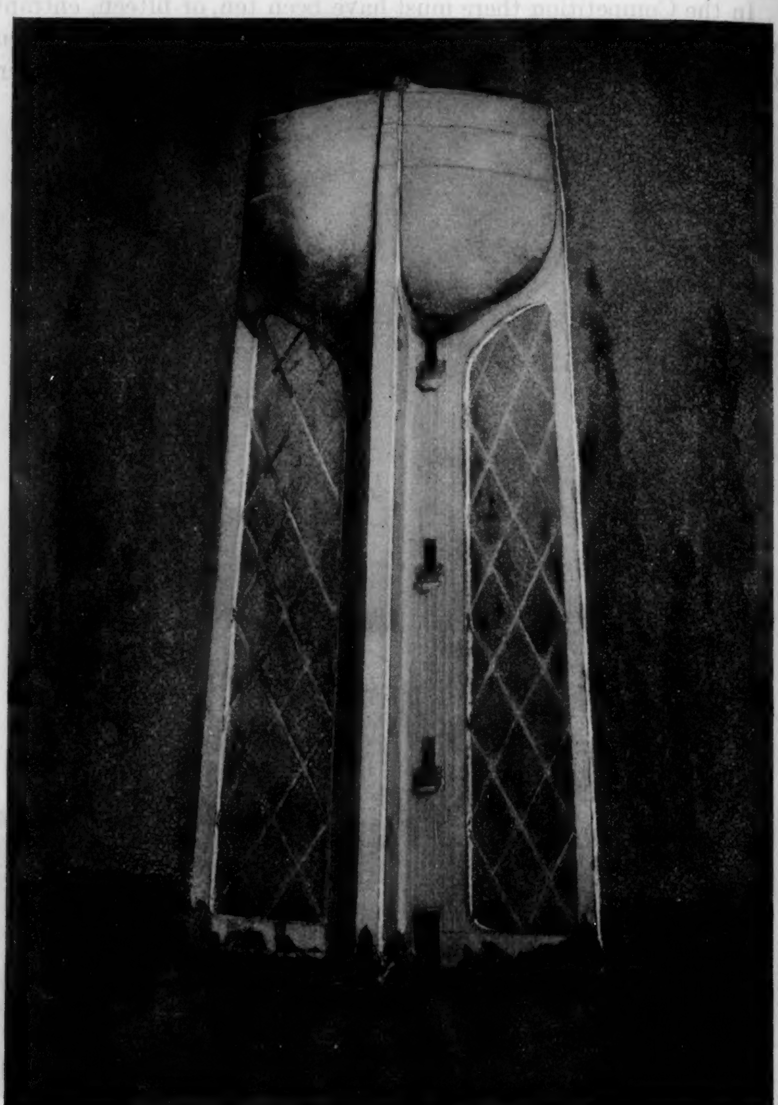


FIG. 2. 1,000,000-GALLON RADIAL-CONE-BOTTOM ELEVATED TANK IN THE SANDUSKY, OHIO, WATERWORKS SYSTEM

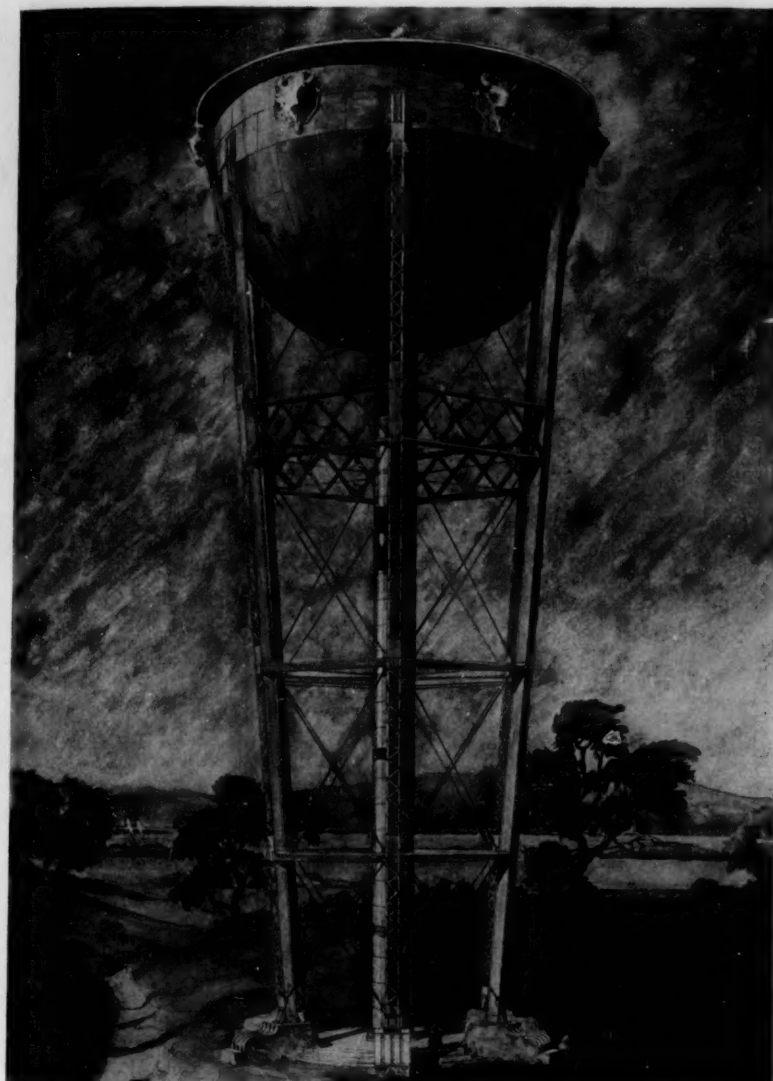
easy to build. I am not arguing one way or another about the appearance of any of them. Look and decide for yourselves.

Figure 5 is quite attractive from the fact that the original drawing



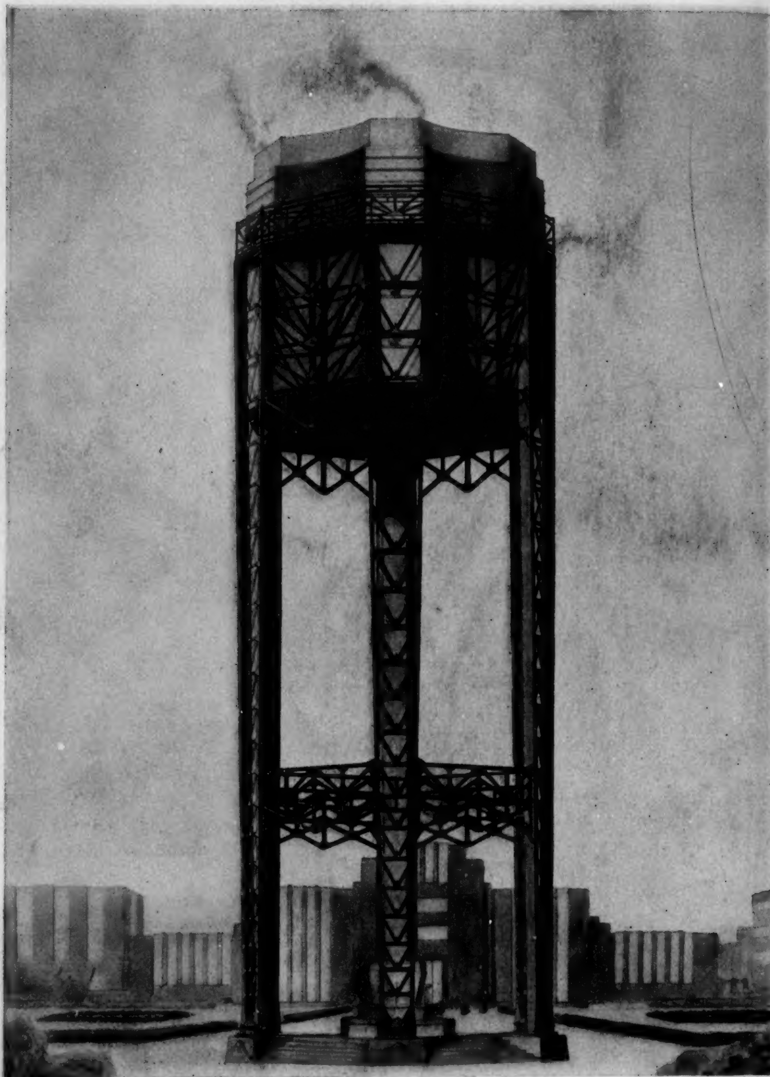
Chas. Stark

FIG. 3. AN INTERESTING DESIGN SUBMITTED IN THE ELEVATED TANK COMPETITION TO DEVELOP AN AESTHETIC IMPROVEMENT IN ELEVATED TANKS



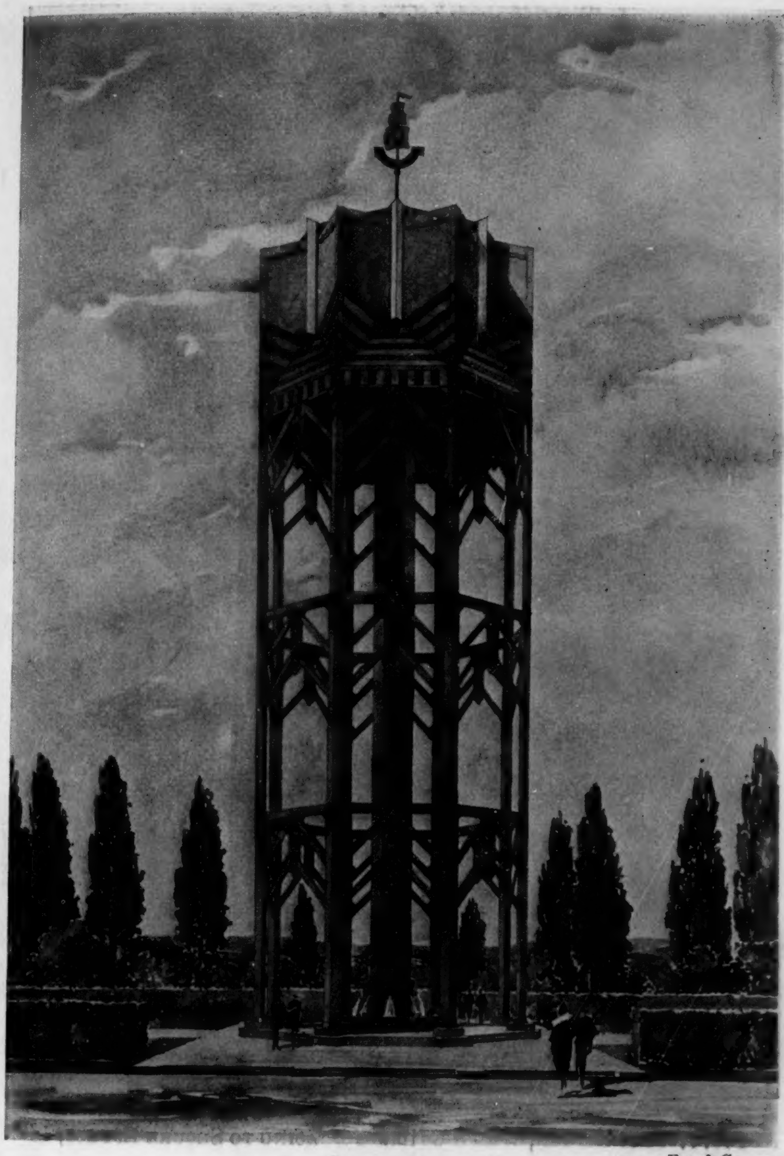
Hubert Ripley

FIG. 4. URN TYPE OF ELEVATED TANK DESIGN SUBMITTED IN COMPETITION



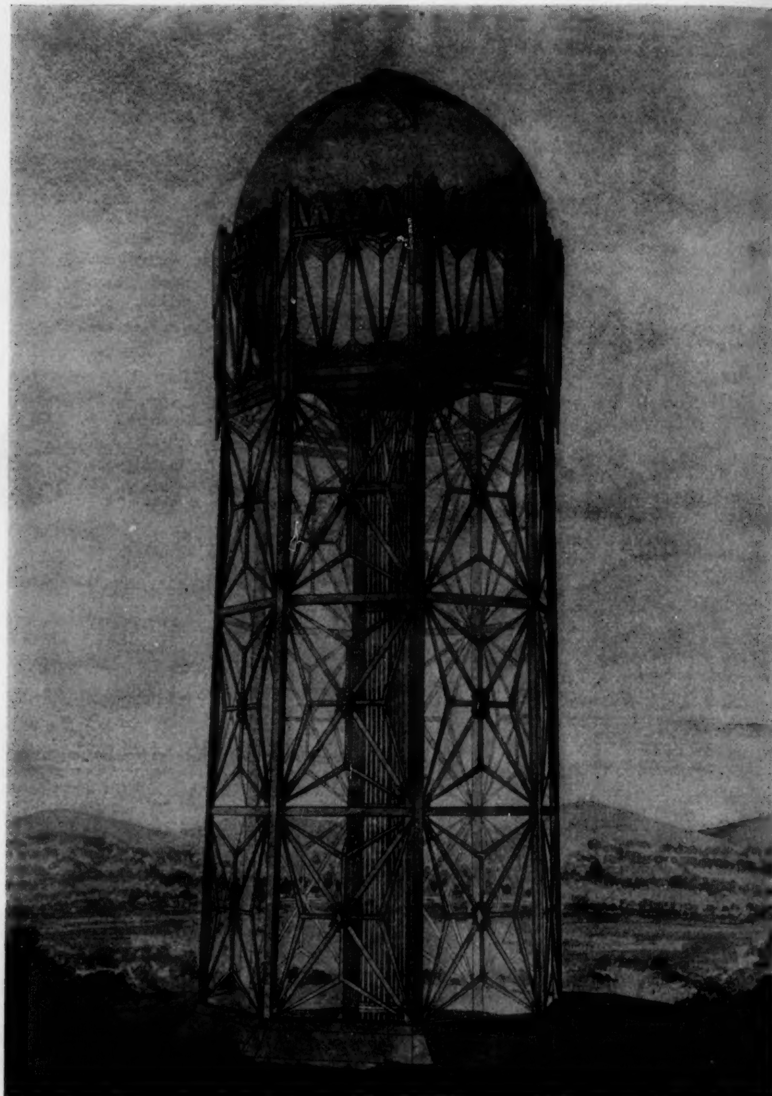
Francis Sabo

FIG. 5. THE SHELL OF THIS TANK HAS AN UNUSUAL SHAPE, REQUIRING EXTERIOR BRACING



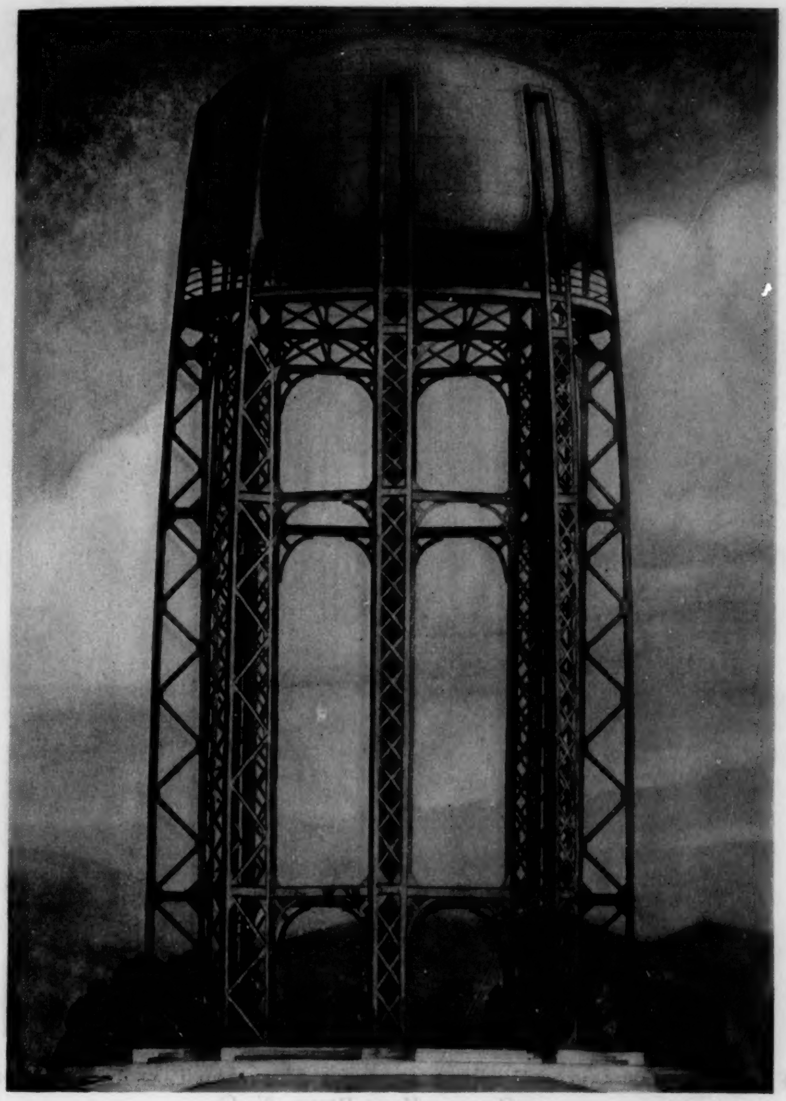
Frank Carson

FIG. 6. THIS DESIGN EMBODIES UNUSUAL SHAPE AND COLORING



Chas. Hartman

FIG. 7. THIS DESIGN, WHICH UTILIZES BRACING TO SECURE EFFECT, IS EXPENSIVE TO BUILD



Donald Blake

FIG. 8. THE LINES OF THIS DESIGN ARE EMBODIED IN THE STRUCTURAL WORK

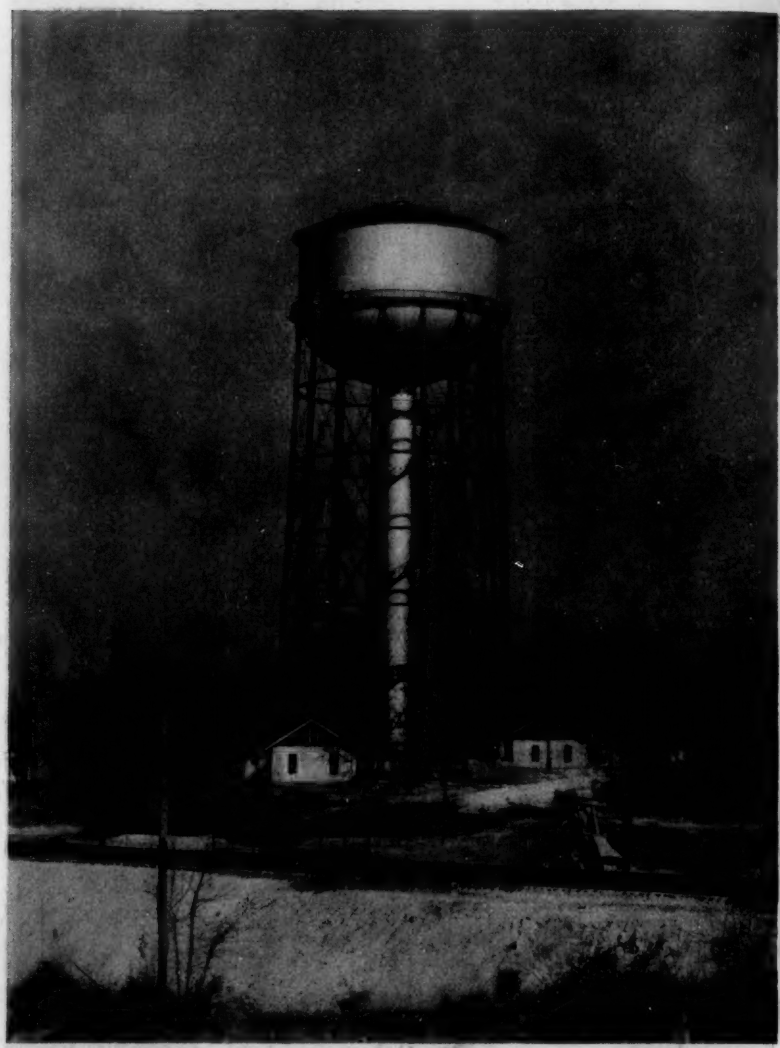


FIG. 9. 1,000,000-GALLON ELLIPSOIDAL-BOTTOM ELEVATED TANK ERECTED FOR THE CITY OF HIGH POINT, N. C.

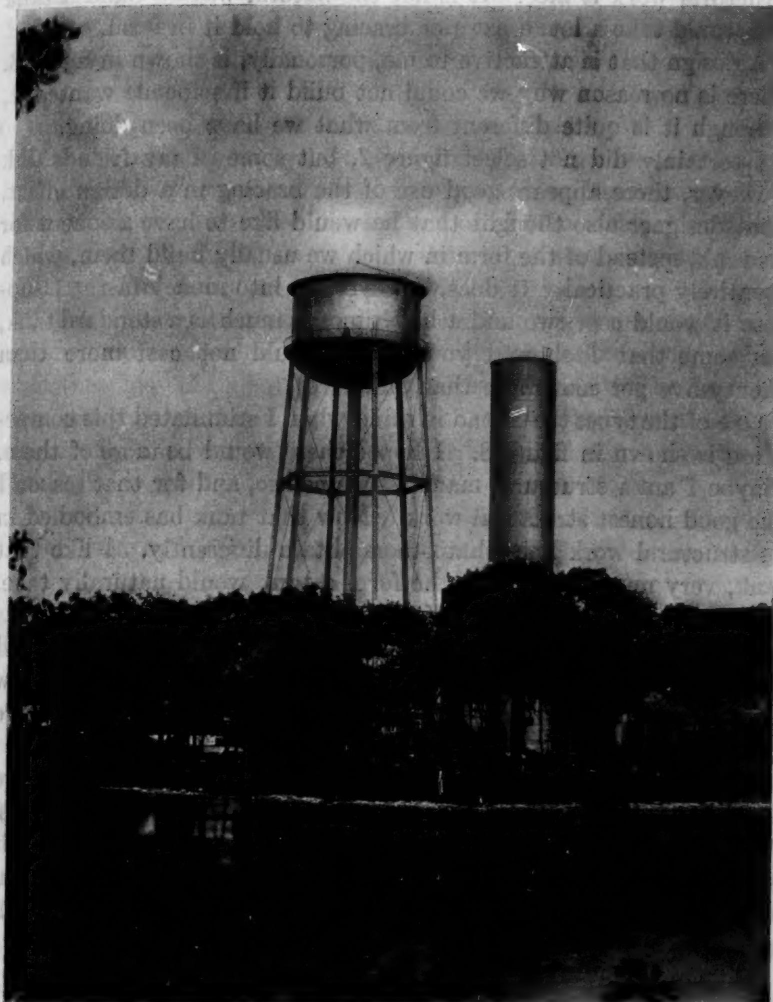


FIG. 10. ELLIPSOIDAL-BOTTOM ELEVATED TANK AND STANDPIPE AT ALLENHURST, N. J.

is brightly colored, but it does not look so well in the picture. The structural work is nice. It is not the natural way to build a tank and would take a lot of exterior bracing to hold it in form.

A design that is attractive to me, personally, is shown in figure 6. There is no reason why we could not build it if someone wanted it, although it is quite different from what we have been doing.

I certainly did not select figure 7, but some of my friends did. However, there appears good use of the bracing in a design effect. That designer also thought that he would like to have a sphere for his tank, instead of the form in which we usually build them, which is entirely practical. It does, however, go into money fast. I suppose it would cost two and a half times as much as a standard tank, but some that I showed you before would not cost more than twenty-five per cent more than standard.

One of the types that I had in mind when I stimulated this competition is shown in figure 8. I hoped there would be more of them. Maybe I am a structural man and trained so, and for that reason I like good honest structural work. Now that tank has embodied in its structural work lines that others obtain differently. I like that tank, very much, since it is the form a tank would naturally take. The surfaces are all curved.

Our standard tank is shown in figure 9, which opens the broad question, how much has this competition really brought out? How much better are these designs than what we have been doing. Here again everybody must make up his mind for himself.

These are all the figures I have to show. I should like to have discussion. I have nothing to advocate. Here are all of these designs. When somebody does not like what we have in a standard form, it is easy to get something else. Furthermore, I think that if you paint your tank in bright colors, most of the criticism we meet will fade away.

Member: I have had to put up some elevated tanks in a residential district recently, and we have had the problem of getting away from the ugly old tanks that we usually have. What has actually been done in beautifying tanks, or making them more acceptable in the way of coloring? I have recently painted three stand towers with aluminum paint, which eliminated some of the objections to them. That is, they do not look so bad. I do not think the people would like to have them in their neighborhood. But I think they

are getting away from the old conventional black and red painting, and they are painting them with aluminum which does not cost so much and, I think, lasts pretty well. That has helped a little bit. But what has actually been done in the way of colors in making elevated tanks acceptable in high class residential districts?

MR. HORTON: Unfortunately, as far as I know, there has been practically nothing done. I have tried a little bit here and there, but we cannot get customers to do it. Once in a while we have painted them white or a cream color, instead of aluminum and that helps. In our own yard we have a tank that is painted aluminum with the tower a pleasant green.

When you go into residential districts you might get some of the women's clubs, or some of the women in the neighborhood to say what they like and what they want, although I do not believe that there are two people who will agree. You know a man and his wife will fight on the way to paint their house. I think that is the thing that we are up against there.

MR. DIXON: I have recently had contact with three large standpipes, two in the East and one in Ohio, each of which, of course, were located on a considerable hill. There is quite a striking land mark there, with each of these. Each of these had a conical roof. I do not think you built any of them. Each of these three standpipes was painted a medium olive color, that is neither a light nor a dark. The particular virtues of that shade, again for the standpipe, would be less valuable, perhaps, I think, than for the elevated tanks. But that certainly gives an entirely different effect than the black, or the aluminum. The olive color will meet with favorable results in almost any shade of sky that you have. It will also go in with the trees around the bottom of the tank. Instead of being an ugly blot on the landscape the results were really very good, and they were approved by some of our lady friends.

MR. HORTON: I just put that up as you were speaking. Is that the color to which you refer?

MR. DIXON: That is a little more on the grass green. It is a little bit lighter than the ordinary pickled olive, and it is a little darker than the sage green.

Mr. Horton: You should remember that some of these ought to make a very good looking tank, with these colors. You do not necessarily have to follow these designs, but I am speaking of the coloring. I would not be surprised if someone on some private estate took advantage of some of them. They are good and certainly make an attractive picture.

Mr. Gibson: There is no question but that paint changes the entire value and you should always use paint. You should have that harmonize with the surrounding buildings, or grounds, so that it will not make a severe contrast with them, or with the sky. In residential districts the thing to do is to buy sufficient land to permit shrubbery and ornamentation. If cedars or poplars, are planted with bushes they will not detract from the appearance of the neighborhood. I know of one case in the South where a tank in a small city has pretty nearly a half a square. The water company has placed a hedge around it and planted a few populars to hide the legs of the tower, and it is a community playground for the children. Every afternoon during the summertime, spring and fall, the nurses are out with the children and instead of being unsightly it is really a pleasant location.

In Charleston we did not put a roof on our tank at first. We painted it with a red lead, and then with aluminum. Later we put on a roof and painted it red. A good many people told me that we spoiled it by putting the red roof on, and others told me that we had improved it. We have got to paint it again this fall, after five years, and perhaps that we will change it. I do not know just what we will do.

I have about a half a square there. I tried to get the Commission to let me beautify it, but it is a rather poor neighborhood at this time, although it is improving. I wanted to plant some poplars around there. They will grow in that vicinity about sixty feet tall, normally, so by the time we get those in, we will pretty nearly hide our tank structure. Mr. Horton said that they were putting in a three million gallon tank, and if it is on the same ratio as ours, I do not think that it will be ugly, but it has locally been christened as a "silver cup" of three million gallons.

Mr. West: We have been adopting an aluminum paint and some very interesting experiences have been undertaken. We have a small

tank about thirty feet in diameter and six feet high. There is a flying field nearby and also one at Port Jervis, a hundred miles away. The tank is aluminum, and it is almost invisible from the village against the sky, but the pilots tell us that when they leave Port Jervis, a hundred miles away, if they go up a thousand feet they pick out that little tank as a sort of searchlight or guide to come back to their own field.

In contrast to that we tried to decide on a color for a tank on the South shore of Massachusetts, and there the pilots objected to the aluminum, but they were a different kind of pilot. These were the pilots on the boats. They said that they could not see it as a landmark, and we would have to paint that one black. As a compromise our tanks were painted aluminum on top, especially the elevated tanks, and the legs were painted black.

MEMBER: The tank we have is a million and half gallons, but it is in a residential neighborhood and in one of the good sections of the city. We anticipated some objection, so on the plans for erection we issued a little pamphlet and distributed it to all of the people in that section of the city. There about thirteen thousand. We had those delivered by hand by our meter readers. All the risers and the supports were painted an olive green and top aluminum, and on the top dome is the air marker leading to the Airport in Indianapolis. There was enough of the spectacular in the little leaflets to arouse interest, and we had the papers behind it, and up to this time we have not heard much criticism.

Of course, the color that we have there now is not causing any favorable comment, but we have assured the people that it will be repainted again, and that makes it all right. We purchased a good sized tract of land and we are going to beautify it. Up to this time we have had very little, if any, criticism.

CHAIRMAN TAYLOR: We will all agree that inasmuch as a very small percentage of the money invested in the water supply systems is above ground where it can be seen, it is well worth while to spend a little more money to have the part that can be seen attractive. I have had passed around little booklets showing the workshop which the Portland plant has erected. It made a very favorable impression on me.

When they first talked about building a workshop, the people

living in that neighborhood were afraid it was going to be an eye sore, but now they say that it has developed the neighborhood to a good one; it is really an improvement. That booklet will show that it really is a very beautiful structure for a workshop. I have a paper which Mr. Graham sent me in description of this, and he says that the cost of the building was very little, not more than ten percent of the main structure. It certainly is well worth while to spend a little more money and make things attractive.

In our own case we keep our pumping station right up to data. It is made of granite, and the surrounding gate houses and screen houses, and other small buildings, are of similar construction. Keeping it clean and attractive gives the people a confidence in your whole system. In other words, if they see a sloppy looking pumping station, or shop, or any part that is above ground, they think the whole system is sloppy, whereas if the part they see is neat and attractive it gives a very good impression of the whole system.

We have pretty nearly exhausted the tank question, but if there is any other discussion on making other parts of the system attractive, we should be glad to hear it now.

Member: Mr. Chairman, I would like to hear some remarks on landscaping.

Chairman Taylor: Has anyone any remarks to make on landscaping? It helps a lot. Around our station we have men who are really competent and do a good job and make the grounds look much better than they might otherwise.

Mr. Gibson: We have about fifteen to twenty acres around our pumping station and entrance into it from the main road. We have simply laid that off and cut the underbrush out. We keep the trees, mostly pine, white-washed up to about six feet from the ground. At night it gives a kind of spectral effect. They look like tombstones, but we are correcting that. We are planting wisteria around most of those trees and that is growing now. Within the next year I think that we will have about two hundred of these pines where the wisteria will have grown to probably two-thirds of their height. or about thirty feet. We have done nothing in the way of lawn, except to mow the native volunteer grass regularly.

We have a rather hard climate, and to keep the grass supplied

with water is expensive, and grasses like men, are lazy. That is, if a man does not have to work to earn his living, he will soon decay. So with grass if it does not have to work to get water it becomes just a top growth. If you do not give the native grasses water they will send their roots down to get the moisture and while in August and September the grass will be pretty well burned up and look as if dead, it requires only a few showers of rain the latter part of September to revive it.

Around the plant we have placed hedges along the walk and roads. Our pumping station building is a long, gable-end type of building with pilasters outside built of red brick. At each pilaster we have planted cedars that grow up in a pyramidal form at a very acute angle. That has improved the appearance of the building and broken it up so that at a distance it looks quite beautiful. We have white-washed the cornices and the pilasters which also relieves the monotony of the long red brick walls. At one end of the building that was just a plain flat wall we have planted ivy. I do not know whether it is a good thing to plant ivy on a building or not, but in our case I do not think it will hurt. Ivy retains the moisture and tends to decay the woodwork at the windows. We expect to replace this woodwork with metal sash and casements as required.

If you have sloppy looking grounds around your building people are going to criticise and say that your plant is sloppy. People who have been out to the pumping station stop me to compliment us upon the appearance of the grounds. I ask them if they went through the filter plant and pumping station and generally the answer is no, but that we have a beautiful place out there and we keep it so clean that they like to drive out as a matter of recreation.

JAMES W. GRAHAM:[2] The service shop and garage of the Portland Water District was erected in 1928 at a cost of $110,000 exclusive of land, and contains 23,300 square feet of floor space.

The building takes the place of the old plant on Kennebec Street which is now offered for sale at a price of $50,000 for the land and buildings.

The first thought for the new building was for a shop building of three stories with garage adjacent and connected therewith. It would have been possible to erect on this lot a substantial building

[2] Treasurer and General Manager, Portland Water District, Portland, Me.

similar to this to answer all the working requirements, but with an appearance no more interesting than a common storehouse such as might be tucked away on some back lot, yet the building could have been efficiently and conveniently planned with the grounds left to take care of themselves. This had been the general type adopted for such buildings in other localities.

The officials of the District visited plants of other cities and gathered all available information. In searching for plans suitable for the new plant, the Trustees sought for beauty as well as utility in order that the neighborhood should not suffer depreciation.

Under the building zoning ordinance, the location on which the building was to be erected was in the apartment house zone. It was therefore necessary to appeal to the City Council for special permission to erect the building. At the hearing, a strong protest was made by the residents in the district adjacent that the erecting of the building would have the appearance of a factory and decrease the property values. The result has been entirely the opposite, and only recently one of the city's prominent real estate dealers remarked that in his opinion the new building has raised the value of the surrounding property at least fifty percent.

The building was designed by John Calvin Stevens, Architect, and is a low rambling structure 350 feet in length, built of brick with concrete foundation and floors. The artistic sloping roof is of fireproof construction and supported by steel tresses.

The wing of the building nearest to Brighton Avenue, 50 by 60 feet, is two stories in height and contains the service department office, stock room, toilets and working space on the first floor. On the second floor are emergency sleeping quarters, locker room, employees rest room, assembly room and kitchen, where during the winter months occasional suppers and meetings are held for the entire personnel of the District, and matters pertaining to the District's welfare are discussed.

The main portion of the building contains a blacksmith's shop, carpenter's shop, and floor space for loading of trucks for service work and general repairs.

The garage is 60 by 100 feet and has a wing in the rear for automobile repair shop.

The tower which forms the focal point of the building is a purely utilitarian feature, but is unlike the usual tower put up for drying hose, and it has become an important part of the attractiveness of the building.

The weather vane is a reproduction of the first street sprinkling cart used in Portland.

The grounds about the building have been carefully laid out with lawns, vines, shrubbery and trees.

The additional cost of making this structure architecturally interesting is a very small percentage of the total cost, being only about 5 percent.

When strangers who come to Portland are being shown the points of interest, this plant is one of the important places, and its unique character and treatment is bound to impress the visitor favorably.

An attractive plant such as this is always sure to awaken the citizens who own it, and to bring about a feeling of pride in ownership.

When water departments have furnished pure water in ample quantity they have performed a vital service, but their service is incomplete, unless the works have been made as beautiful and attractive as possible and have thus furnished that appeal of higher things which elevate the human being into something more than a money-making machine.

Water is essential to the life of a city, but as regards the health of the people and the protection of property. Every citizen should be vitally interested to know that the water served him is pure in quality, and ample in quantity to give protection to his property when fire threatens. One sure way to awaken his interest is by making the water-works property attractive.

A public building like that of the Portland Water District would be failing in its purpose if it did not prove to the community and to the world at large that the interests of all the people were given careful consideration, and it was a pleasant experience of the architects who designed it that the Trustees of the Portland Water District were desirous of achieving such a result.

RECORD MAPS OF DISTRIBUTION PIPES AND VALVES

A. S. Hibbs:[1] I have divided this discussion into four different topics; first, the source of information, that is, the information obtained in the field or on the job; second, the preparation of maps in the office from this information; third, the office records maintained by the department, and fourth, the valve operators record books that are used in locating valves.

During my water works experience, I have had occasion at different times to revamp several systems of water works records. Usually in a department that has been operating for some time, it has old records which are not always the best for reference purposes, which have become worn through constant use, and which are not easily available for field use in the matter of operating valves and locating mains for future extensions. I found that it was very necessary that this information be consolidated into one type of record drawing.

In Akron, Ohio, we had five different sets of books, or record, which were developed from time to time and to which it was necessary to refer at times for valve locations. We took all these records and tried to combine them into one source of information for the benefit of our valve operators and repair crews.

In Cincinnati, where I am now located, I found we had three or four different sets of records, but the one which was most accurate is the old system of service branch books, which were made up on eggshell card board and bound into large canvas covered books, and which have been handled and corrected for thirty or forty years. Some of these books are dog-eared and dirty from handling and it is almost impossible to read them any longer and we, therefore, find it is absolutely necessary to draw new maps of the entire city for our mains and service branches.

It was necessary in Cincinnati to cover the entire County in making up a new set of records, since we read all meters, turn off and on all services, and make all repairs on the water mains.

The former records only covered the City, but now with the new

[1] Superintendent, Department of Water Works, Cincinnati, Ohio

sanitary district system of building water mains, out into and all over the County, it is rather important to have complete records.

Using a United States Topographical Survey map of the County as a base, and dividing it into rectangles 6400 by 8000 feet, an index sheet was formed, which was marked alphabetically from west to east across the County and numerically in even hundreds from north to south.

Each of these rectangles when enlarged to 400 foot scale, forms a drawing 16 by 20 inches, which spaces nicely on a 17 by 22 standard loose leaf page. Loose leaf canvas bound covers are available in this size at a nominal cost, and can be obtained easily as needed.

A system of sub-indexing has been arranged so that should the density of the details to be shown require, subdivisions can be provided to scales of 200, 100 or 50 feet to the inch.

While the same alphabetical index will govern these subdivisions, the 400 foot sheet will carry a number in even hundreds; the 200 foot sheet will be numbered in twenties, such as twenty, forty, sixty; the 100 foot sheet will have numbers ending in one, five or even tens, and the 50 foot sheets will have numbers still further subdivided, ending in one, two, three or four.

The final sheets, whether a 400 or 50 foot scale is used, are all of the same dimensions, 17 by 22 inches with standard punchings for the loose leaf books previously mentioned.

It is possible, on the 400 foot sheets to show simply a skeleton of the mains, without street lines or buildings.

Then on another sheet of similar outside dimensions, arranged so that it faces the drawing on the book as a left hand page might, a simple table is provided, each valve on the drawing being numbered, with numerical index on the table giving the size, make, number of turns to close, direction of closing and actual location of the valve.

This plan follows greatly the system of valve locations used by the City of Los Angeles.

In the City, where it is necessary to show more detail on account of the closeness of the houses, the 400 foot sheet can be used as an index, cutting it up into sheets enlarged to a 50 foot scale, which gives us an opportunity to show each service branch and all the main details of the system, using at the same time a sheet on the opposite page for the valve locations and detailed descriptions.

Or a 400 foot sheet can be divided partly in 200, 100 or 50 foot sheets as necessary.

We can do almost anything that we wish with this system for it is very flexible.

All working drawings are made on that same size sheet, 17 by 22 on a 50 foot scale, so that filing is simplified, and standardized system is maintained and the transfer of data to our record sheets is readily made.

For the valve operators and repair crews, we are at present using loose leaf books 11 by 14 inches in size, with heavy fibre covers, for which photostat copies of the regular record drawings are made.

Thus we have a system that can be used in our drafting room for record and reference, in our Commercial Division at the Application counter for reference in taking applications for new service branches, in our Engineering Division in laying out proposed new mains, and for our repair and maintenance gangs on turning off and on valves and service branches.

In the preparation of these sheets, we prepare our final records on tracing cloth, books for valve and maintenance crews on photostats, and construction drawings on tracing paper, using blue prints of such drawings for filing purposes.

REPORT OF COMMITTEE ON FEDERAL INCOME TAX

This Committee recommends that:

The American Waterworks Association make a formal protest against the present policy of the United States Department of Internal Revenue as announced under date of October 24, 1930, by the Commissioner, and under which policy the compensation of municipal waterworks employes is declared to be subject to the Federal Income Tax, and that the Association give both its moral support and financial assistance to the necessary legal action, begun by the Association or by one or more of its individual members, to substantiate its claim that in attempting to collect income taxes from municipal waterworks employes the Federal Government is acting beyond its constitutional authority.

Your Committee, appointed by the Board of Directors at its January, 1931, meeting, believes such action by the Association is imperative. We call your attention to the legal steps already taken by Chas. S. Denman, General Manager of the Des Moines (Iowa) Waterworks, in appeal to the United States Board of Tax Appeals and his determination to have this issue decided by the court of last resort. The Association is indebted to him in this matter.

The municipal waterworks employes of the United States are represented by this Association more than by any other. The Association exists for the purpose of service in the water works field, and in the issue at hand there is a service to be rendered that requires positive action. The burden of the issue should not be left to individual members. It requires collective and coöperative action, and now is the time to act.

Our conclusions and recommendations are based upon the following summary of information concerning the announced policy of the Internal Revenue Department, the application of that policy and the results therefrom as gathered during the past few months from members of this Association and others by correspondence and study from thirty-five states. The main question under consideration is the so-called Federal Income Tax as related to compensation of Municipal Water Works employes since 1924.

1. The Commissioner of Internal Revenue stated the departmental policy on October 24, 1930, in It.-Mimeograph Number 3838–571, and also in letters of April 4, 1931, and April 17, 1931, substantially as follows:

"The compensation of all officers and employes of a state, or a political subdivision thereof, is subject to the Federal Income Tax unless they are engaged in the discharge of an '*essential governmental function*.' The present Federal Income Tax Law is *silent on the subject* of taxing the compensation of such officers and employes; but the policy now being pursued by this Bureau is in accordance with various decisions of the Supreme Court of the United States and other courts."

The Supreme Court is quoted in support of this policy (Fiint vs. Stone Tracy Company, 220 U. S. 107), as follows by the Commissioner:

"It is no part of the essential governmental functions of a state to provide means of transportation, supply artificial light, water and the like. These objects are often accomplished through the medium of private corporations. . . .

"The true distinction is between the attempted taxation of those operations of the states essential to the execution of its governmental functions, *and which the state can only do itself*, and those activities which are of a private character. The former the United States may not interfere with by taxing the agencies of the state in carrying out its purposes; the latter, although regulated by the state, and exercising delegated authority. . . . are not removed from the field of legitimate Federal taxation."

2. A somewhat curious expression of this policy is found in the same published rule of the Department as follows:

". . . . It is held that the supplying of water, light and power to the inhabitants of a community and the operation of refrigerating plants constitute the discharge of a proprietary function and the compensation of the officers and employes of such plants is subject to the Federal income tax, *except such as are employed in the sewerage department and the department supplying water to the fire department of the city, as the operation of a sewerage department and a fire department constitutes the discharge of an essential governmental function.*"

Deductions for purposes of computing Federal Income Tax are therefore legal in cases of water works employes whose compensation in whole or part is for services in connection with fire protection and sewerage.

3. Beyond this expression of policy we can expect little from the Revenue Department or the Board of Appeals. This issue must be carried to the Supreme Court of the United States. If the operation

of a municipal water works (the supplying of water for all purposes) is not an essential governmental function in this day and age, it is our duty to find out how far the Federal Government will go and can go in attempting to further tax the proprietary instruments of the states. It is the opinion of eminent attorneys that, if the supplying of water by a municipality is a proprietary function, not only will municipal water works salaries be subject to the income tax, but Congress would also have the right to tax the income from the bonds, debentures or other obligations issued by the municipality to support the water works or any proprietary function.

4. We find that the application of the policy to tax municipal water works salaries has not been uniform throughout the various taxing districts. This may be due in part, however, to the existence of different conditions governing the operation and management of a municipal water works in the various states and municipalities. Neither Federal Government nor municipal officials should be surprised at the misunderstanding which exists. Our investigation reveals a chaotic condition which emphasizes the necessity of action on the part of this Association which will bring the Association and its members closer together in an effort to solve this problem by coöperation with Federal Tax officials or by litigation, or both, as seems necessary.

5. We consider the following outline as a fairly adequate cross-section of the situation throughout the country as to the collection of the Federal Income Tax on the salaries and compensation of municipal water works employes.

1. INSTRUCTIONS FROM LOCAL OFFICIALS

Verbal and written instructions emanating from local tax officials with respect to this tax are by no means uniform. Most of this advice, information and instruction has been verbal. In a few instances written instructions have been given. This is best illustrated by the following instances as to liability of water works employes for this tax.

(a) An engineer in a water department in a large eastern city was advised by the collector in charge of the territory involved that his salary was exempt from taxation, while in another city in the same state water works officials were notified that they must pay the tax.

(b) Another employe in a southern city has paid the tax regularly

because the local collector suggested that it would be better for him to do so.

(c) In a Tennessee city the tax was paid under protest on demand of the local officials and appealed, which appeal was not allowed. Another appeal has been taken.

(d) In a New England state the salary of the clerk and attorney of a water district was, after tax was paid and upon appeal, exempted on the ground that the district was a subdivision of the state and refunds were made. The local collector in the first instance demanded payment of the tax.

(e) In a middle west city the local collector and his associates have repeatedly and verbally advised water works officials that their salaries were not taxable and even refused to accept tax returns when offered. In another city in the same state payment of tax was demanded.

(f) In a Massachusetts city water works employes were advised verbally each year that they were exempt. Now Federal officers are demanding a return, with interest and penalties for non-return in the past.

(g) The collector in a large city in a wsetern state advised a water works engineer that he must pay the tax which was paid. A refund was asked for 1926, 1927, 1928 and 1929. The refund claim was officially declared to be without merit, but the claimant received a refund for two of the four years in spite of the refusal to grant it.

(h) In a large middle west city the local income tax office advised a water works employe that it would not be necessary to file returns and accordingly none have been filed.

(i) In several cities water works officials have been formally advised to make a return, but have not done so, believing their salaries exempt.

(j) In a southern city a water works superintendent has paid a tax on 25 percent of his salary, as that part of the water works system which is paid out for water rates, for the past four years, but no allowance was made for fire protection work.

(k) In a southern city of another state the water works employes were asked in 1925 to make payments covering back years. The matter was taken into Federal Court and a decision handed down that they were not subject to the tax. No tax has been paid since this decision.

2. PAYMENT OR NON-PAYMENT OF TAX

Out of 89 replies to the direct question to 134 water works officials in 37 states, "Have you paid any Federal Income Tax on your salary as a municipal water works employee?", we find that 38 say *no* and 51 *yes*. In some instances the answer was individual and in others for the department as a whole.

3. DEDUCTION OF SALARY FOR FIRE PROTECTION WORK

In only two instances, *one* in California and *one* in Missouri, has any deduction been made on account of fire protection work. In all other cases the replies state *no* as to such deduction even though in many instances such a claim might have been made.

4. TAX ON SALARIES OF OTHER MUNICIPAL EMPLOYES

We find the following employes are taxed:

Park	Lowell, Mass.
Electric light and steam heat	Lansing, Mich.
Electric light and power plant	Glenndale, Calif.
	Los Angeles, Calif.
Light and power plant	Pasadena, Calif.
City and Mountain Parks	Denver, Colo.
Light Plant	Jacksonville, Fla.
Street railways	San Francisco, Calif.
Recreation Employes	Detroit, Mich.
Parks and Hospitals	St. Louis, Mo.
City Gas and Electric	Holyoke, Mass.

5. RETURNS CLAIMING EXEMPTION

Returns claiming exemption from the income tax have been few and far between and seem to have received scant attention from tax officials. Protests and payment of taxes under protest have availed little or nothing.

The case of Theodore A. Leisen, General Manager of the Metropolitan Utilities District of Omaha, should be referred to here. Since January 1, 1927, he has made tax returns, but has not included his salary. He paid the tax under protest in 1925 and 1926. He has filed a formal protest and requested a hearing claiming exemption as an employe of a political subdivision of the State of Nebraska, engaged in administering governmental functions of the State of Nebraska, and the City of Omaha, which is a political subdivision of the State of Nebraska, by reason of the provisions of the Consti-

tution of the United States, denying the right of the Federal Government to tax the states or political subdivisions thereof, and by further reason of the provisions of Section 1211 of the Revenue Act of 1926 and subsequent legislation. This protest is still pending.

The brief cites uniform rulings of the Board of Tax Appeals from and after the passage of the 1926 Revenue Act in support of his claim. They are of such importance as to merit a brief recital here.

In *Appeal of Durkin*, 4 B. T. A. 743, (1926), the Board held that the salary of the Superintendent of the Bureau of Water of the City of Syracuse was exempt from income tax under Section 1211 of the Act of 1926.

In *Mathews v. Commissioner*, 8 B. T. A. 209, (1927), a county attorney's salary was held exempt, citing 5 B. T. A. 1047 and 1135, and 6 B. T. A. 827.

In *Coffin v. Commissioner*, 12 B. T. A. 702, (1928), it was decided that the trustees appointed by the state to temporarily manage the Boston Elevated Railway in the interests of the public, are exempt from income tax.

In *Mathews v. Commissioner*, 13 B. T. A. 1133, (1928), the legal counsel for the Los Angeles Board of Public Service Commissioners, having jurisdiction over municipal water and electric plants, was held entitled to exemption on his salary under Section 1211 of the Act of 1926.

In *Strickland v. Commissioner*, 16 B. T. A. 419, (1929), the exemption was extended to the attorney for a Texas Water Improvement District.

In *Frank v. Commissioner*, 16 B. T. A. 771, (1929), the exemption was extended to the attorney for an Ohio River Conservancy District.

In *Young v. Commissioner*, 16 B. T. A., 1428, (1929), the legal counsel for the Indiana Coal & Fuel Commission was held exempt.

In *McDonough v. Commissioner*, 16 B. T. A. 556, (1929), the attorney for an Arkansas Bridge District was held exempt.

In *Jones v. Commissioner*, 17 B. T. A. 1131, (Oct. 1929), the legal counsel for a Missouri Drainage District was held exempt.

All of the foregoing rulings of the Board of Tax Appeals were based on Section 1211 of the Revenue Act of 1926, and on the theory that the claimant was an officer or employe of a state or political subdivision thereof, rather than on the general principle of constitutional law that officers or employes engaged in performing governmental functions of the state of a political subdivision are exempt.

6. LEGAL ACTION

Two important actions have been taken which should be referred to in this report.

1. The first one involved the Portland Water District (Maine) and its very efficient and well known clerk and attorney of the Board, David E. Moulton.

The Portland Water District was incorporated by the Legislature and expressly declared to be a public municipal corporation, with sole powers of supplying water for domestic and municipal purposes to various cities and towns. The District claimed exemption from the Federal Income Tax for salaries paid to its officials as a political subdivision of the State of Maine. Prior to the law of 1926 they were able to maintain that position, although Mr. Moulton's salary as clerk and attorney was taxed in 1922, 1923 and 1924. Upon appeal, however, refunds were granted by the Commissioner and the case dismissed. Mr. Moulton has succeeded in establishing his claim that both prior to and since 1926 he is both an officer and employe of the Portland Water District—a political subdivision of the State of Maine, but has been assessed a tax on his salary upon the ground that supplying water is not a governmental function.

This is no doubt an important decision, as there are other similar water districts in the United States.

In discussing this question Mr. Moulton has written to your Committee as follows:

"The Income Tax authorities are continually attempting to prove in my case that my services as Clerk and Attorney are not established by law and that I am neither an officer nor an employe, although by stipulation with the representatives of the United States Board of Tax Appeals, as above mentioned, my contention to the contrary was upheld. The Department does hold, however, and I think with some merit, that the supplying of water even by a city is not a governmental function and on that ground that the salaries are subject to taxation.

"It is unquestionably true that there are a line of decisions practically unanimous in all of the states that, when a city goes into the business of supplying water, gas or electricity, it does so under all of the obligations that a private company would be under in doing the same work, and that the city is liable for the neglect or negligence of its employes engaged in these duties, while the city would not be liable for negligence of its police officers, fire department and other officers engaged in what is generally conceded to be governmental duties.

"I believe that it will be necessary for a test case to be taken to the Supreme Court of the United States to establish whether or not the United States Government has authority to determine what is a governmental function. In my opinion, when a state declares that it will undertake the business of supplying water, it is just as much an essential element of its governmental work as is the maintenance of a fire department. The question of liability for income taxes on the salaries of municipal water works employes depends as the law exists today upon this constitutional question. Undoubtedly under the rulings of the Income Tax Department, such salaries are not exempt. If there

is any constitutional right in the United States Government to assess such a tax, they have assessed it. I would like to see the question carried to the Supreme Court and would be very glad to render any assistance in my power as an attorney with some experience in such matters, if I can be of assistance to your Committee."

2. The second action referred to is the Appeal to the United States Board of Tax Appeals by Chas. S. Denman, General Manager of the Des Moines (Iowa) Water Works, U. S. B. T. A. 44026 and 38030, in which he claims exemption for the years 1926 to 1930, inclusive, after denial of exemption by the Collector and Commissioner. The Appeal is pending. He proposes appeal to the Courts if his claim is denied by the Board of Tax Appeals, and he will be represented by eminent counsel. Mr. Denman has made all his papers in this case available to the Committee but only a brief reference can be made to the fundamentals of the case in this report. His position and that of his attorneys is well stated in understandable language in a letter to United States Senator Dickinson as follows:

". . . . the argument of the department seems to be that our Water Works is engaged in a non-essential business and that the earnings, during the last ten years amounting to over $1,500,000.00 and the bonds amounting to $5,500,000.00, must not be taxed because the revenue law exempts them, but because the law says nothing about the employees that they do not come under the exemption. If they would tax the bonds and the earnings on the grounds that it is not essential for the city to run its own Water Works I would have no word of complaint. . . . I am not sure . . . . that the Revenue Department understands all that there is in it in connection with the distinction which has been made between governmental and proprietary functions. I think that most of the cases which have been decided with reference to these distinctions have been cases in which the courts have held that if a municipality goes into business, it must be bound by its contracts just as a private individual is. What a state may do depends upon the powers which it holds under its constitution and the Federal Constitution. Whatever the state itself does is of necessity a governmental function. The state is a government and its functions are governmental functions. Within the limits of its constitutional powers it is for the state to determine what these functions shall be. If the United States may tax them at its discretion, then the United States has practically taken this power away from the states. I cannot imagine any functions of a government to be other than governmental functions. . . ."

This is not merely a question of protecting the interests of a relatively few water works officials or of municipal park, recreation, steam, electric light or other officials. It is part and parcel of the great struggle to prevent further encroachment of the Federal

authority upon local and individual responsibility—the building up of a centralized bureauacracy at the sacrifice of the rights of the states. We must continue to have both national power and local power, but in the field of taxation we must dispute the asserted authority of the Federal Government to determine what is a local governmental function.

We believe each state has the right to determine for itself what governmental function it will undertake, and that it is beyond the power of the United States to tax such instrumentalities of government.

Respectfully submitted,

WM. W. BRUSH,
HOWELL WRIGHT,
SAMUEL B. MORRIS.

DISCUSSION

METERS FOR CUSTOMERS' NEEDS

I have read the excellent article by F. R. Berry entitled "Meters Suitable for Customers' Needs" in the August, 1931, JOURNAL.

While I believe most of the points discussed in the paper are very well taken, may I be permitted to call attention to a few statements made therein with which my experience extending over a considerable period of years of water plant operation and management does not allow me to agree?

Mr. Berry states: "The compound meter also has the advantage of lower initial cost and lower maintenance cost. It has the disadvantage of having somewhat higher friction losses, ... ". My experience has been that, considering meters of the same size, every meter company charges more for a compound meter than for a displacement meter. A compound meter consisting as it does of practically two complete meters plus a balanced valve has at least twice the number of working parts as a similar sized displacement meter, and it is reasonable to suppose that the maintenance cost would be considerably higher than for a simple displacement meter, and this I have found to be true.

Data sheets now before me indicate that for any given size and discharge, the compound meter has a considerably lower friction loss than for the same sized displacement meter. Of course, it may have been Mr. Berry's intention in making these statements to rely upon the considerably greater capacity of a compound meter over a displacement, and install the next size smaller compound in place of any given size displacement. Under this condition, the compound meter would have a lower initial cost, and perhaps somewhat higher friction losses, but as this is not stated in the article, we must assume compound and displacement meters of the same inlet and outlet sizes.

The article also states: "At locations where the flow during a large proportion of the time is supplied through the current section" (referring to the compound meter, of course) "some trouble has been experienced in keeping the displacement section of the meter in good

operating condition as it operates so infrequently that it becomes stuck." This statement may be true of some makes of compound meters, but some are so designed that the displacement section of the meter operates continuously regardless of whether or not the current section carries most of the load, and because of this design the displacement section can never become stuck because of operating infrequently.

F. W. HARTMANN.[1]

FILTER SAND

Data presented in the paper by J. W. Armstrong[2] are completely contradictory to the data heretofore published on the relation of rate of wash water application to expansion of the sand bed. The author's observation is that when the expansion is plotted against the rate of aplication of wash water the resultant characteristic line is curved, the higher rates having a proportionately greater effect in increasing the expansion. In contrast to these findings, those presented by the writers in The JOURNAL, November, 1929, p. 1479, invariably indicated a straight-line relationship for the 38 curves formally reported. Each of these curves was determined by plotting 15 or more observed points, so that the observations cannot be dismissed for lack of thoroughness. Similarly, the experiments at Cincinnati, reported by Ellms and Gettrust in the Transactions of the Am. Soc. of C. E., 1916, p. 1342, indicated the same straight-line relation between sand rise and rate of wash.

Lacking a detailed description of the apparatus from which Mr. Armstrong's data were obtained and of the technique used in conducting the experiments it is impossible to account for this discordance. It must remain the task of other experimenters conducting carefully controlled investigations to verify the facts of the case. It may be suggested, however, that an accurate calibration of the diameter of the experimental filter tube throughout its entire length is essential to correct analysis of the data. If, for example, the area of the tube should be smaller toward the top, as the sand bed expands the actual rate of wash-water application will be greater than that indicated by a measurement of the discharge alone. The result would be a disproportionate increase in the sand rise at the higher rates and a curving expansion characteristic, unless the true wash

[1] National Meter Company, Chicago, Ill.
[2] JOURNAL, September, 1931.

rate were determined by dividing the discharge rate by the actual average area of the tube in the length in which the wash is effective. Conversely, a tube larger at the top should tend to make the expansion characteristic curve in the opposite direction. Further, it is important that the water temperature should be constant throughout any single experiment or curvature will result. It may be, as suggested by Mr. Armstrong, that the earlier studies did not carry wash rates high enough to make the curvature evident, but as those experiments included observations on expansions up to 65 or 70 percent it is felt that they covered adequately the probable range of usefulness in waterworks design and operation. If expansions much greater than these must be used before a curved expansion characteristic is obtained the question of the deviation from a straight line becomes largely academic.

There is one point, however, on whch Mr. Armstrong's reasoning is not convincing. In differentiating between the washing behavior of uniform and graded sand, the following paragraph appears:

"If the ratio of rise of sand to the rise of water be taken as the coefficient of sand expansion, it can readily be seen that each different size of sand has a different coefficient. Obviously, it is not possible to plot three points having different coefficients and draw a straight line connecting them. Therefore, the law of sand expansion for a graded sand bed is rightly expressed by a true curve and not by a straight line. The fact that velocity enters into the equation and $V = \sqrt{2gh}$ indicates the curve to be one of the second degree."

Although the first two sentences are true enough, the conclusion drawn from them is entirely false. The "law of sand expansion" under discussion is the relation between rate of wash and its effect upon the volume of an *invariably constituted* bed of sand and not the relation between the expansion effect and sand grain diameter. Even though the diameter of the grains should vary from top to bottom of the bed, during the course of the experiment the sand bed as a whole has not had its size characteristics altered and all the sand grains, fine and coarse, have been acted upon by the wash water, at high and at low rates of application. Further, the use of the kinetic expression, $V = \sqrt{2gh}$ has no relevance whatever unless the symbol h is identified with some dimension under discussion. There are many formulas containing a velocity expression of the first degree of the second, third, sixth or any degree desired. To choose any one of them at random and base a conclusion thereon as to the shape of the sand expansion curve would clearly be unjustified. That would be just as reasonable, however, as the selection of $V = \sqrt{2gh}$.

In the next paragraph Mr. Armstrong admits the possibility of a straight-line expansion characteristic for a bed of perfectly uniform sand. From that assumption it can be demonstrated that a bed of graded sand should behave in a similar manner. For example, a 25-inch depth of sand made up of five 5-inch layers, each composed of uniform sand but varying in size from layer to layer, would constitute a bed of graded sand. There is no reason to believe that any of these layers would behave differently when forming a part of the 25-inch bed than it would when acting independently. The expansion of the entire bed would be equal to the sum of the expansions of the component layers, and as the characteristic expansion curve for each layer would be straight, that of the entire bed would likewise be straight.

From the arguments advanced under the heading "Essential Facts in Washing," Mr. Armstrong has apparently concluded that better cleansing will be obtained with lower degrees of bed expansion. Observations at both Detroit and Cleveland lead to the opposite conclusion. Furthermore, Mr. Armstrong states later in his paper that "our experiments with the small glass filters point very strongly to the desirability of using much higher rates (of wash) than have been considered proper heretofore." If higher rates are used the result will inevitably be the higher sand expansions previously adjudged most undesirable.

ROBERTS HULBERT,[3]
F. W. HERRING.[4]

[3] Filtration Plant, Water Department, Detroit, Mich.
[4] Engineering News-Record, Chicago, Ill.

SOCIETY AFFAIRS

THE ANNUAL CONVENTION

The first session of the fifty-first annual convention of the American Water Works Association was called to order by President Fenkell at 11 o'clock on Monday morning, in Pittsburgh, May 25, 1931 It was held in the Cardinal Room of the Hotel William Penn.

The members were welcomed by E. G. Lang, Commissioner of Public Works, who substituted for Mayor C. H. Kline, of Pittsburgh, the latter being very ill. Mayor Kline sent his greetings to the convention through Commissioner Lang. President Fenkell expressed his appreciation of the work of preparation for the convention by John E. O'Leary, Chairman of the Local Committee. He also commended the Hotel William Penn for the coöperation in this work, and referred to the splendid coöperation by the water works manufacturers of the Pittsburgh area in contributing to the success of the convention. Lastly Mr. Fenkell spoke of the efficiency of the arrangements by Secretary Little and his staff of the American Water Works Association office, especially of A. V. Ruggles and W. M. Niesley, Assistants to the Secretary.

Award of the Diven Medal

The Chair explained that this medal is presented annually to the active member who, in the judgment of the John M. Diven Medal Committee, has done most for the Association during the past year. He called on Stephen Taylor, Superintendent of New Bedford, Mass., Chairman of the Committee to present the medal.

Mr. Taylor announced that the man chosen for this honor was Malcolm Pirnie, Consulting Engineer, New York City, for his work as Secretary of the Standardization Council, and, later, as Chairman of the Committee on Water Works Practice, through whom all of the important committees on the "Manual of Water Works Practice" function.

In accepting the honor, Mr. Pirnie spoke of the influence that John M. Diven had exercised on the destinies of the Association during his life and the spirit with which this had inspired the members. He

then gave an outline of the work accomplished by the Committee on Water Works Practice, and what it was proposed to do.

Chairman Fenkell said the officers and members felt that they had honored themselves in the selection of Mr. Pirnie as a recipient of the medal.

Engineering News-Record Award

The Chair then read a letter from Colonel Chevalier, offering an award from the Engineering News-Record in memory of John M. Goodell, to take the form of a certificate and probably a money award, the terms to be decided after a conference between the Board of Directors of theAssociation and Colonel Chevalier.

William W. Brush moved the acceptance of the award which was seconded by Prof. Edward Bartow, University of Iowa, and carried.

The next report was by the committee on Income Tax of Water Works Employees. This report was given by Mr. Brush who said that the tax on employees has been remitted up to 1925, so that it was not retroactive before that date. Since that time wide variations of rulings had been made by income tax men in charge of various districts. He then asked Howell Wright, Cleveland, a number of the Committee and a lawyer to give some data he had collected on the subject.

Mr. Wright recommended that a formal protest be made by the Association against the present practices of the Internal Revenue Bureau and that the body give its moral and financial support to the men who are carrying on the fight against the taxing of municipal water works men. He referred to the appeal by Mr. Denman, Superintendent of Des Moines, Iowa, and said that the Association was indebted to him for his fight against the tax. Mr. Wright cited a number of cases where conflicting decisions has been made as regards the payment of the tax. He said the fight must be carried to the United States Supreme Court and now was the time to do this. He also referred to the cases of Colonel Leisen of Omaha, Nebr., and clerk Moulton of the Portland, Maine, Water District.

The report was referred to the Board of Directors with the sense of the membership that the Association should actively protest against and endeavor to prevent the taxing of employees of municipal water works.

The reports by Secretary Little and Treasurer Brush, showed the Association in excellent financial condition and growing in membership.

A note of warning was sounded by both officers that in the present depression all must be prompt in settling their indebtedness to the Association.

Chairman Fenkell announced the election of the officers, to take office on the last day of the convention, as follows:

President, Ross L. Dobbin, General Manager, Utilities Commission, Peterborough, Ont., Canada.

Treasurer, William W. Brush, Chief Engineer, Department of Water Supply, Gas and Electricity, New York City.

Plant Management Division and Round Table Discussion

The Monday afternoon session was the first meeting of the Plant Management and Operation Division, with Stephen Taylor in the Chair. The first topic for discussion was "Non-Shock Water Pressure Ratings of Fittings" (as related to the proposed changes in standards). The discussion was opened by H. A. Hoffer, Eastern Sales Manager of the United States Pipe & Foundry Company, Philadelphia. This question was discussed by William W. Brush, who took a strong stand against the proposed change in standards and offered a resolution to this effect, which was carried.

Subject No. 2, "Lead for Pipe Joints," was freely discussed by the members present after the discussion was opened by E. G. Bradbury.

The third topic was "Record Maps of Distribution Pipes and Valves." The discussion was led by A. S. Hibbs, Superintendent, Cincinnati, Ohio.

Topic 4, "Rates for Outside Water Consumers," was discussed by Wm. W. Brush, S. B. Morris, L. W. Thompson, E. G. Bradbury, A. Carle Rogers, and J. W. McEvoy.

The last topic to be discussed was "Use of Cast Iron Pipe in Lengths Longer than 12 Feet." This discussion was opened by N. B. Lyle, Scranton Spring Brook Water Service Company.

It was further discussed by F. B. Larmon, Stephen H. Taylor, William W. Brush, David Heffernan and others.

This concluded the Monday afternoon session. In the evening the "Service des Eaux" held its annual dinner. The day closed with an informal reception and dance.

Tuesday, Morning Session. The first paper of the Tuesday morning session was called for by President Fenkell at 9.30 o'clock on the "Economy of Universal Meterage," by E. A. Johnson, Pittsburgh Equitable Meter Company. The paper was discussed by L. D. Gayton.

The two papers which followed were on various phases of Pittsburgh's water problems, and were illustrated with lantern slides. The first was on "The Pittsburgh Water Works and Pressure Zoning," by James H. Kennon, Managing Engineer, Bureau of Water. The second dealt with the "Effect of Acid Mine Drainage on River Water Supply," by Chester F. Drake, Division Superintendent, Pittsburgh Filtration Plant, Aspinwall.

Mr. Brush moved a vote of thanks to city and water works authorities of Pittsburgh for the excellent arrangements of the convention. This was seconded by Samual B. Morris, of Pasadena, Cal., and carried.

The final paper of the session was by Paul Hansen, Consulting Engineer, Chicago, on "Tastes and Odors in Water, Causes and Remedies."

The paper was discussed at some length by John R. Baylis, Roberts Hulbert, L. I. Birdsall, Geo. D. Norcom, and others.

Tuesday, Afternoon Session. The first paper of the Tuesday afternoon session was on "Corrosion of Water Mains" by F. N. Speller, J. W. L. Birkinbine and R. D. Redington, all of the National Tube Company, Pittsburgh.

A paper followed on "Diversion of Water Works Funds" by Howell Wright, Attorney, Cleveland, formerly Director of Utilities of the City of Cleveland.

The paper was discussed by Mr. Gibson, who spoke strongly against the diversion of water works funds for any purpose, but for the water works department.

The next paper was an important one and was illustrated by lantern slides. It was entitled "Personnel Problems in American Water Works," and was read by C. A. Dykstra, City Manager, Cincinnati, Ohio.

This paper was discussed by Mr. Brush. He emphasized the necessity of paying the personnel a sufficient salary to insure the employment of capable individuals. This was especially true of the Superintendent. He must be a leader, for much of the success of such a system depends on leadership. The average compensation in the water works department is entirely too low.

The final paper of the session was on "Gravel Wall or Gravel Packed Wells," by F. T. Quinn, Jr., Layne & Bowler, Inc., Memphis.

The paper was discussed by Leon A. Smith, Superintendent, Madison, Wis.

Finance and Accounting Division Luncheon

At noon a luncheon was held by the members of the Finance and Accounting Division. There was a large attendance and the toastmaster, called upon each man present to rise and announce his name and connection. Those who were called upon to address the members were Hal Smith, President of the Division; President Fenkell of the Association, Malcolm Pirnie, winner of the Diven Medal, and William Orchard, of the Purification Division.

Dinner of Purification Division

The annual dinner of the Purification Division was held at 7 p.m. on Tuesday. William Orchard was Toastmaster, and the entertainment was announced as "A Ten Round Bout." As usual the dinner was both entertaining and instructive.

Bridge and Luncheon for Ladies

A bridge luncheon was tendered to the ladies of the convention at the Country Club at 12.30 p.m.

Wednesday, Morning Session. A paper on "Recent Developments in Elevated Tanks for Distribution Systems," was presented by J. O. Jackson, Chief Engineer, Pittsburgh-Des Moines Steel Company.

The paper was discussed by W. C. Mabee, Chief Engineer, Indianapolis Water Company.

A paper, on "Allocation of Streams" was prepared by Harold Conkling, Deputy State Engineer of California and in the absence of Mr. Conkling was read by Mr. S. B. Morris.

The paper was discussed by Nathan B. Jacobs, Vice President, and Arthur Skilling, Assistant Engineer, Morris Knowles, Inc.,

Mr. Leon T. Eliel, Pacific Manager, Fairchild Aerial Surveys, Inc., Los Angeles, Cal., read an interesting paper in which he showed the value of aerial maps in the plotting of the sites of reservoirs and dams, and the determination of the formation of the terrain, especially in inaccessible places. Afterward, in such cases when the site is finally decided upon, the maps, he said, would be found to be of great value.

The paper was discussed by James W. Armstrong and W. N. Brown.

The final paper of this session was the "Colorado River Aqueduct of Southern California Cities," by Julian Hinds, Designing Engineer, Metropolitan Water District of Southern California, Los Angeles. This paper was read by Mr. S. B. Morris in the absence of Mr. Hinds.

The paper was discussed by Thaddeus Merriman, Chief Engineer of the New York City Board of Water Supply and Chairman, Engineering Board of Review of the Southern California District.

Water Purification Division Meets with a Full House

The sessions of the Water Purification Division were all very well attended—in fact, at some of the sessions the meeting room was overtaxed. The opening session occurred in the Blue Room of the hotel at 2 o'clock on Tuesday, with Chairman Baylis presiding. The first paper was by Chester F. Drake, on the problems and difficulties confronting superintendents in mining and industrial districts. The paper was discussed by Edward C. Trax, and H. E. Moses.

Other papers read at this session of the division were: "Manganese in Water; Its Occurrence and Removal," by Robert Spurr Weston. A Symposium on Filtering Materials for Water Works was opened by Wm. E. Stanley, Chairman, A.S.C.E. Committee on Filtering Materials for Water and Sewage Works.

A discussion of "Experimental Work on Filter Sand," was opened by James W. Armstrong.

Papers read at the second session of the Division were as follows: "The Chemistry of Chloramines," J. F. T. Berliner. "The Revivification of Granular Activated Carbon for Water Purification," by Paul Mahler and H. B. Crane. "A Study of the Bactericidal Efficiency of the Ammonia-Chlorine Treatment," by H. H. Gerstein. "Combating Tastes in West Virginia Public Water Supplies in 1930," by E. S. Tisdale. "Ammonia Salts in Taste Elimination," by Harry E. Jordan. "Results of Taste and Odor Control with the Ammonia-Chlorine Treatment at Beaver Falls and New Brighton, Pa." by E. C. Goehring. "A Resume of the Ammonia-Chlorine Treatment at Cleveland," by W. C. Lawrence.

A paper descriptive of the "Laboratory and Plant Results with Activated Carbon at Bay City's Filtration Plant," was read by Louis B. Harrison.

Malcolm Pirnie spoke on the subject of "Experience with Powdered Activated Carbon."

A paper that attracted considerable attention was on the effect of fluorine in water supply on the enamel of growing teeth, by A. P. Churchill, of the Aluminum Corporation of America.

The Wednesday afternoon session of the Purification Division was devoted to discussion of topics for the revision of the Manual of Water

Works Practice. This is part of the work of Committee 5, Quality and Treatment of Water, Paul Hansen, (Chairman).

The election of officers at the business session of the Water Purification Division resulted in the following:

Chairman, Paul Hansen; Vice-Chairman, Joseph W. Ellms; and Director, John R. Baylis.

Resolutions of condolence were passed by the Division on the deaths of Allen Hazen and W. F. Monfort, long members of the Water Purification Division.

The Plant Management and Operation Division

Wednesday, Afternoon Session. A symposium on "Operating Experiences with Gate Valves as Related to Needed Improvements in Design" was opened by Seth M. Van Loan, who was followed by Loran D. Gayton, H. W. Griswold, J. A. Jensen, S. B. Morris, A. U. Sanderson, J. T. Skinker, and F. H. Stephenson.

Service Pipe Materials were discussed by James E. Gibson. His paper was in the nature of a progress report, as Chairman of the Sub-Committee 7-F of the Water Works Practice Committee.

A discussion of Mr. Gibson's report was read by Howard S. Morse.

Colonel Leisen moved a resolution of the sense of regret of the Association on the loss sustained by it in the recent death of Allen Hazen. Mr. Morse seconded the resolution, and it was carried by a rising vote.

Smoker in the Evening

The members and guests were entertained in the "Pirates Hall" of the Hotel by a smoker and entertainment until a late hour.

Thursday, Morning Session. The Thursday morning session consisted of a meeting of the Plant Management and Operation Division with the Chairman of the Division, Stephen Taylor, in the chair. The opening statement on the subject "Pipe Corrosion—Corrective Measures" was by Malcolm Pirnie.

A number discussed this question, among them being E. L. Bean, James M. Caird, Edward S. Hopkins, Robert S. Weston and E. G. McConnell.

Mr. Arthur T. Clark read a paper on this subject, illustrated with lantern slides.

Sub-Aqueous Pipe Lines were discussed by H. L. Clark. Stephen H. Taylor in discussing the subject described a pipe line to an island

colony at New Bedford, Mass. After the line had been laid at 30 feet below surface, the government decided to dredge a channel and the line had to be again lowered.

Mr. George C. Horton, of the Chicago Bridge and Iron Company, gave a talk on the design of elevated tanks. He showed a number of designs submitted by contestants in a recent competition conducted by his company, and considerable discussion ensued as to the best design of such tanks and standpipes. Among those taking part were Messrs. Gibson, Clark, Dixon, Huy, Jordan, Gregory, Rebsamen, and others.

The chair then called upon Mr. Gibson, as Chairman of the Nominating Committee, who proposed the following officers for the ensuing year:

Chairman—A. F. Porzelius.

Vice-Chairman—Leon A. Smith.

Secretary—A. V. Ruggles.

Directors—T. A. Leisen and Stephen H. Taylor. These officers were unanimously elected.

Finance and Accounting Division

The Finance and Accounting Division held its first session at 9 a.m. on Thursday, with Hal F. Smith, Head Clerk, Water Consumers Accounts, Department of Water Supply, Detroit, Chairman of the Division, in charge. A Round Table discussion on the theme: "Office Management Accounting and Records," was the first feature, with L. M. Anderson, Controller, Department of Water Power, Los Angeles, in the chair.

The first discussion was on "Installing an Accounting System in a Small Plant," by Ralph A. Hoot, Water Works Engineer, Detroit; the second, "What Are the Advantages of Stub Accounting?" by Lawrence M. Bailey, City Controller and Water Superintendent, Lincoln Park, Mich.; the third, "What Progress is Being Made with the Application of Tabulating Machines to Customers' Accounting?" by John H. Kimball and R. M. Sedgqick, Accountant and Assistant Accountant-Secretary of the East Bay Municipal Utility District, Oakland, Cal.

Other phases of this theme discussed at this session were "How Many Accounts Are Necessary for the Practical Application of Mechanical Billing Equipment?" by W. P. Adams, Public Utility Division, Boroughs Adding Machine Company, Detroit, Mich.;

"The Permanent Meter Reading Book versus Temporary Meter Reading Slips," by Carl K. Chapin, Commercial Director, Los Angeles Department of Water and Power; "Printed Forms and Their Control," by J. H. Johnson, Public Utility Service Department, Remington-Rand Business Service, Inc., Buffalo, N.Y., and "The Theme Discussed from the Canadian Point of View," by A. B. Manson, General Manager, Public Utility Commission, Stratford, Ont., and R. M. Bond, Auditor of Municipal Accounts, Hydro-Electric Power Commission of Ontario.

Thursday, Afternoon Session. "The 1930 Drought and Its Lessons" were considered in a symposium on Thursday afternoon at the main session, with W. W. DeBerard in the chair. There were two opening statements, one by F. R. Berry, Engineer, American Water Works & Electric Company, New York City, and Reeves J. Newsom, Vice-President, Community Water Service Company, New York City.

The symposium was divided into four parts. The first of these was "Need for Reappraising Customary Design as to Yield of Supply Source and Peak Load Capacities That Should Be Provided in Supply Source, Purification Works, Distribution System and Connecting Parts." The speakers on this topic were Paul Hansen, John F. Laboon, N. T. Veatch, Jr., and Ezra B. Whitman.

The next section of the Drought Symposium was on the "Need for Better Records of Rainfall and Stream Flow as a Basis for Forecasting Watershed Yields." This subject was treated by John C. Hoyt, Hydraulic Engineer, U. S. Geological Survey.

At the conclusion of Mr. Hoyt's paper, the chair referred to the illness of W. S. Cramer, Chief Engineer of the Lexington, Ky., Water Company, and "Father of the Plant Management and Operation Division," and called on Mr. Gibson to speak on the subject. Mr. Gibson offered a resolution of sympathy for Mr. Cramer and hope for his speedy recovery. This was carried by a rising vote and similar resolutions were ordered sent to George W. Fuller, New York City, "Father of the Standardization Council," who is also ill.

Winner of the Hill Cup

It was announced that the Pacific Northwest Section of the Association is winner of the Nicholas H. Hill Cup, as the section showing the greatest gain in membership for the year, namely 14 per cent. This is the second time the section has won the cup. The Southeastern Section was a close second, with a gain of 11 per cent. The Southeastern won the cup last year.

The third section of the drought symposium was on "Effect of Drought on Water Quality." This discussion was by James W. Armstrong, F. C. Dugan, H. F. Ferguson, Martin E. Flentje, Thomas R. Lathrop, George D. Norcom and C. E. Trowbridge.

The final subject of the symposium was "Emergency Water Relief Measures During Drought," by F. C. Dugan, H. F. Ferguson, Thomas R. Lathrop and H. E. Moses.

Finance and Accounting Division

The subject of "Public Relations" was taken by the Finance and Accounting Division at its Thursday afternoon session, with Hal F. Smith in the chair. It was discussed by A. P. Michaels.

Mr. Howard S. Morse presented a paper on "A Rating Scale for Public Relations," in the nature of a report of Committee No. 9 of the Water Works Practice Committee.

Another paper of this session on Service Rating Methods was by Joseph F. Majeske, Director of Personnel, Detroit Water Supply Department. This paper described the application to Detroit of the same system as that described by Mr. Dykstra as having been applied to the Water Department of Cincinnati, Ohio.

The final paper of the session was on "Purchasing by Competitive Bidding," by Charles J. Afke, Comptroller, Hackensack Water Company, Weehawken, N. J.

Dinner Dance

A largely attended dinner-dance took place on Thursday evening. The dinner was held in the Pirate's Hall of the hotel, and the dancing took place in the Cardinal Room.

Friday, Morning Session. There was only one session on Friday morning, that of the Finance and Accounting Division. D. C. Grobbel, Secretary of the Detroit Water Department, presided, Charles J. Tobin, attorney, of Albany, N. Y., led the discussion, with a paper on the subject of the "State Franchise Tax."

Other discussions on this theme were as follows: "Trend of Rate Structure in Michigan Cities," showing a distinct tendency towards the adoption of the A.W.W.A. Standards by G. D. Kennedy. "Perpetual Plant Inventory," E. E. Bankson and Nathan B. Jacobs. "Depreciation Allowance for Federal Income Taxes, Louis D. Blum, "Water Service and Local Taxes." J. Mark Wilcox, "Marketing Public Utility Securities," H. Gordon Calder.

"Committee Report: Standard Classification of Accounts." F. H. Gorman. This report was read by Louis Blum, in the absence of Mr. Gorman.

At the business meeting of the Finance and Accounting Division the following officers were elected:

Chairman—A. P. Michaels; Vice-Chairman—A. B. Manson; Directors—Hal F. Smith and F. C. Jordan.

ABSTRACTS OF WATER WORKS LITERATURE[1]

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Lining the Beacon Hill Sewer Tunnel at Seattle. Eng. News-Rec., 104: 442–4, March 13, 1930. The 5580-foot tunnel now being built under Beacon Hill in Seattle to convey sewage from the borders of Lake Washington to Elliott Bay is being lined with concrete to give circular section with inside diameter of 9 feet. Because of stable quality of the clay which tunnel traverses, the timber lining put in as tunnel was driven consisted of ring made up of 15 segments, the concrete lining being later poured inside this ring. Up to level of the spring line, wood panel forms are used and lower half of the concrete lining is poured by gravity. For the arch, collapsible steel forms are used, and in these concrete is placed by pneumatic process. Present contract was made after a 4- x 6-foot pilot tunnel had been driven in about 3700 feet from west portal to explore the formation. Present operation, therefore, consists in (1) enlargement of this pilot bore to a circular section of about 12 feet diameter and (2) driving remaining 1880 feet to east portal. Construction methods are described and illustrated.—*R. E. Thompson.*

Probable Cause of Premature Tunnel Explosions. WILLIAM SMAILL. Eng. News-Rec., 104: 700, April 24, 1930. An investigation made in connection with a stick of dynamite, which exploded while a powderman holding an electric torch in his hand was starting to unwind the wires from the stick which contained a late delay exploder, showed that when the switch in this particular torch was opened to the operating position and one leg of the detonator wire was in contact with the cover of the torch and the other with the plunger switch the detonator invariably exploded. Only one other torch of similar construction was found. It is now believed that the premature explosion which occurred last November on the 15-mile tunnel being driven for the Metropolitan Water District was caused by use of a similar torch.—*R. E. Thompson.*

Uniform Aggregate Specifications in Use in Detroit. L. G. LENHARDT. Eng. News-Rec., 104: 655–6, 1930. The aggregate specifications of the Detroit Engineering Society, which have been widely adopted in Detroit, are given.—*R. E. Thompson (Courtesy Chem. Abst.).*

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[1] Vacancies on the abstracting staff occur from time to time. Members desirous of cooperating in this work are earnestly requested to communicate with the chief abstractor, Frank Hannan, 285 Willow Avenue, Toronto 8, Ontario, Canada.

Causes of Concrete Disintegration. F. R. McMillan. Eng. News-Rec., 104: 735–6, 1930. A discussion of the paper by Merriman (cf. C. A., 24: 1718). A survey of more than 600 structures in U. S. has shown that where disintegration of concrete occurs it is almost universally confined to parts of the structures where defective concrete has resulted from improper methods of manipulation. It is pointed out there is as yet no proof that the behavior in Na_2SO_4 solutions is any indication of the performance which may be expected of a cement under normal concrete use.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Portable Auto Spotlight Handy in Tunnel Work. Aaron Evans. Eng. News.-Rec., 104: 776, May 8, 1930. Brief illustrated description of a portable light devised for use of inspectors in Seattle's Hanford Street sewer tunnel, consisting of heavy-duty plug, short piece of rubber cord, two 50-watt 8-16-24-volt bell-ringing transformers, about 20 feet of cord, toggle switch, and an ordinary automobile spotlight mounted on a wooden handle. Common automobile bulbs were used and usually the 16-volt connection on the transformer, an intense white light being obtained. More satisfactory service would be given by a 150-watt transformer with an easy voltage regulator.—*R. E. Thompson.*

The Art of Water Filtration. George G. Nasmith. Cont. Rec. and Eng. Rev., 44: 303–4, 1930. Brief general discussion in which it is pointed out that treatment of every water supply is an individual and distinct problem. Preliminary studies are of inestimable value in designing a purification plant.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Reservoir Control for Mississippi Suggested by 1927 Flood Data. Eng. News-Rec., 104: 488, March 20, 1930. In recently completed study of data for 1927 flood on Mississippi River, J. P. Kemper suggests possibility of holding back flood peaks by means of reservoirs to such an extent as to reduce the greatest floods to the capacity of the improved channel between Arkansas and Red rivers. With such control, no diversion through the Boeuf valley would be necessary for protection of the Tensas basin.—*R. E. Thompson.*

Constructing Framed Mattress for Mississippi Revetment. Eng. News-Rec., 104: 720–4, May 1, 1930. Illustrated description of mattress structure, method of fabrication, and sinking process.—*R. E. Thompson.*

Tower-Excavator Performance and Costs on Three Types of Levee. Morris W. Gilland. Eng. News-Rec., 104: 510–6, March 27, 1930. Illustrated description of tower-excavator outfit for levee construction used on Mississippi River flood control project, and extensive data on performance and costs on new levee, set-over levee, and levee enlargement. The originally well-thought-of performance of 30,000 cubic yards per month has been increased to well over 180,000 cubic yards per month with a single 10-hour shift day during the past 10 years.—*R. E. Thompson.*

Development of the Dragline Excavator: A Universal Earth-Moving Tool. J. C. French. Eng. News-Rec., 104: 556–9, April 3, 1930. Illustrated description of the development of the dragline excavator and its applications.—*R. E. Thompson.*

Water Works of Ontario. A. E. BERRY. Cont. Rec. and Eng. Rev., **44**: 289–90, 307, 1930. Data on water supplies of Ontario (cf. C.A., **24**: 1689). A large number of water supply improvements are in progress or projected. There is an increasing demand for palatability.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Water Supply and Sewerage of Large Japanese Cities. HAROLD E. BABBITT. Eng. News-Rec., **104**: 729–31, 1930. The water supplies and sewage disposal systems of a number of Japanese cities are described. Osaka, with a population of 2,408,000, derives its water supply from the Kamo River, purification being effected by coagulation with alum and slow sand filtration. A rapid sand filtration plant is under construction. Complete sewage treatment by the activated sludge system is planned. Tokyo, with a population of 2,294,000, obtains its supply from the Tama River, the purification plant consisting of slow sand filters. The daily consumption in 1927 averaged 46.7 gallons per capita. The sewage of the city is treated by sedimentation. At Nagoya the water supply, derived from a surface source, is also treated by slow sand filtration, the effluent exceeding the requirements of the U. S. Treasury Department standard. The first full-size (10–15 million gallons per day) activated sludge plant in Japan is approaching completion in this city. At Kyoto a combined water and power project draws its supply from Lake Biwa. Both slow sand and rapid sand (tub) filters are employed. The water supply of Kobe, drawn from a surface stream, is purified by slow sand filters and by rapid sand filters constructed in 1929. Yokohama's water supply, derived from Sagami River, is also treated by slow sand and rapid sand filtration. Water consumption in 1928 was 47 gallons per capita per day. The sewage is discharged into the sea without treatment. The filters at the cities of Keijo and Jinsen, treating Han River, are of the slow sand type. The water supply of Dairen, obtained from a small impounded stream, is also treated by slow sand filtration. The per capita consumption at the latter city is 33 gallons per day.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Chemical Used to Thaw Fire Hydrants. Eng. News-Rec., **104**: 651, April 17, 1930. Brief outline of method employed in Evanston, Ill., for thawing hydrants. Hydrant cap is unscrewed and a mixture of 25 percent caustic soda and 75 percent aluminum chips (by volume) is poured in on top of the ice. From 2 to 4 pounds of the mixture is sufficient to thaw hydrant in less than 5 minutes. Immediate flushing avoids the danger of corrosion. The method has been employed for 3 years at cost per hydrant between $0.60 and $1.—*R. E. Thompson.*

Sanitation in China as Noted by an American Engineer. HAROLD E. BABBITT. Eng. News-Rec., **104**: 484–7, 1930. Discussion of sanitary conditions in China, with brief notes on water supply and sewerage in coast cities. Sanitation is of very low standard, but water-borne disease is uncommmon, probably because of Chinese habit of consuming only hot drinks. Only one city, Canton, was found which possessed a water works constructed and operated by Chinese. These works were constructed with private capital and operated under private man-

agement until the past year, when they were taken over by the municipal government without compensation to the owners. There are sewers in nearly all the large cities, but there is no city which possesses a complete sewerage system. Many of the sewers are open ditches which serve also as canals for transportation as anchorage for houseboats in which Chinese families dwell, and as sources of water supplies. The habit of conserving, with meticulous care, all inedible organic matter for use as fertilizer minimizes the pollution of surface waters and the load on water filtration plants. The water works of Tientsin, Peking, Tsingtao, Shanghai, Hong Kong and Canton, are outlined. The treatment employed, in general, consists of slow sand or rapid sand filtration preceded, in some cases, by coagulation and followed, in most instances, by chlorination.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Welded Pipe Structures Widely Used in the Oilfields. Eng. News-Rec., **104**: 698, April 24, 1930. The method employed in oil fields in making connections to pipe lines is described and illustrated. A connection with two 45° joints has been found to be much stronger than a direct, unsupported right-angled connection. A brace, consisting of a curved piece of metal cut with the torch from a short length of pipe of same diameter as pipe-line (16-inch in case illustrated) is welded across the angle between pipe and branch line to increase the strength and rigidity of joint. These pipes operate under gas pressures of more than 400 pounds per square inch.—*R. E. Thompson.*

Improvements to Hamilton's Supply. A. E. Berry. Cont. Rec. and Eng. Rev., **44**: 285–8, 1930. As result of complaints regarding taste and turbidity in water supply of Hamilton, Ont., an investigation was conducted by the Ontario Department of Health. The supply is drawn from Lake Ontario, the only treatment employed being chlorination. Turbidity at times renders chlorination ineffective, tap samples collected in December and January last showing heavy contamination. Taste is believed to be due to phenols, probably originating in trade wastes and sewage discharged into Hamilton Bay. Trouble experienced in dyeing plants is believed to be due to high Fe content, which on one occasion was found to reach 7 p.p.m. It is recommended that a filtration plant be constructed immediately, that duplicate chlorination apparatus be installed to ensure continuity of treatment, and that the program of sewage disposal be proceeded with in order to reduce the contamination of Hamilton Bay.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

A Review of Hamilton's Waterworks System. Cont. Rec. and Eng. Rev., **44**: 277–84, March 12, 1930. The history of the Hamilton, Ont., water works since its inception in 1859 is reviewed.—*R. E. Thompson.*

Cost of Yard-Dipping Pipe. Eng. News-Rec., **104**: 456, March 13, 1930. The cost of yard-dipping of pipe during installation of a gas system in Merrill, Wis., averaged as follows: 2-inch pipe, \$0.0299; 3-inch, \$0.0437; 4-inch, \$0.0535 per foot, including materials, labor, etc. The pipes were dipped first in enamel and later in whitewash. It was originally intended to use the whitewash only during hot weather, to protect the enamel against sagging, but it was found

advantageous to use it at all times as it caused the enamel to set quickly and prevented sticking to the skids. The pipe lengths were lifted with sockets about 6 inches long, made from pipe of the next larger size, which also served to cover the ends and protect the threads.—*R. E. Thompson.*

Cross-Connection Elimination War in Texas Cities. W. N. DASHIEL and EDGAR WHEDBEE. Eng. News-Rec., **104**: 444–5, March 13, 1930. The Texas Department of Health takes the position that cross-connection of any public water supply system with any other supply except an approved public water system is potentially dangerous. There are no statutes prohibiting such cross-connections and none of the large cities have adopted regulations to that effect. Progress has however been made through an educational program conducted by State Department of Health with co-operation of domestic quarantine division of U. S. Public Health Service in its program of certification of water supplies used by interstate common carriers. Data are given on progress in several cities, particularly Dallas, where survey made in 1929 disclosed 44 cross-connections, of which 8 were readily eliminated. A survey of the secondary supplies revealed 4 derived from shallow dug or driven wells and 3 from grossly polluted sources, whereas the remainder compared favorably as to potability and safety with primary supply.—*R. E. Thompson.*

Diversion of Water from Niagara Falls. J. J. TRAILL. Cont. Rec. and Eng. Rev., **44**: 401–2, 1930. Brief outline of method employed in computing and controlling diversion at Niagara power plants to keep within provisions of 1909 treaty, which permit 36,000 second-feet within province of Ontario and 20,000 second-feet within state of New York. A method of rating the units was so devised that the amount of water used can be determined from the amount of power generated. Control of the diversions is vested in International Niagara River Board of Control.—*R. E. Thompson (Courtesy Chem. Abst.).*

Constructing a Natural Gas Line of Record Size. Eng. News-Rec., **104**: 600–3, April 10, 1930. One mile of pipe per day per crew of 175 men is being laid on the record-size 26-inch electrically welded natural gas line being built from Kettleman Hills field to the San Francisco Bay region, a distance of 200 miles. Field methods employed by the 2 crews are described. The trench is dug by a ladder-type trencher except in a few places where rock excavation is required, coverage of 2 to 6 feet being provided for. The 26-inch diameter electrically welded steel pipe is made from $\frac{3}{8}$-inch plate in 40-foot lengths. The lengths are placed on skids over the trench and tack-welded into sections of about 10 lengths each. The joint between lengths includes a bell on each pipe and a chill ring which is fitted into the bell of the pipe in the dollies just before the other length is put in position for the first tack weld. The use of the double bell and chill ring eliminates direct pressure on the welded joint and greatly facilitates welding process. Each welding crew consists of 11 welders, 12 generator sets, 1 maintenance man, and 1 foreman. When working at rolling welding, members of these crews make 20 welds per day of 10 hours. From previous experience, it is estimated that acetylene welders would not complete more than 3 such welds in same time. Each one-mile section is tested to 100 pounds

pressure with air. Pipe receives priming coat and second coat of asphaltic paint before being placed in trench.—*R. E. Thompson.*

Earthquake Resistance Provided in Design for Gravity Dam. Eng. News-Rec., 104: 606, April 10, 1930. Provision for earthquake resistance is being incorporated in design of the Pine Canyon dam to be built on the San Gabriel River as part of water supply project for Pasadena, Cal. Preliminary plans call for concrete gravity dam, straight in plan, 295 feet high above streambed and 375 feet above lowest foundations. Structure will contain approximately 700,000 cubic yards of concrete, and reservoir capacity will be 64,200 acre-feet. Exploration tunnels and shafts are now being driven at the site. To provide for earthquake resistance, base width was increased to 0.8 of height, which adds 9.38 percent to volume of structure. Results of studies made, including outline of the mathematical analysis, were given in paper presented before the Seismological Society of America by S. B. Morris and C. E. Pearce. The design principles given in that paper are outlined. It is recommended that provision against earthquake shock should receive consideration in the design of all dams where such forces may be expected.—*R. E. Thompson.*

The Advantages of Water Meters. Herbert Pruden. Cont. Rec. and Eng. Rev., 44: 297–8, March 12, 1930. A general discussion.—*R. E. Thompson.*

The Rapidly Extending Use of Chlorine in Sanitation. Norman J. Howard. Cont. Rec. and Eng. Rev., 44: 291–2, 1930. The use of chlorine in sanitation, which dates back to 1854 when an English Royal Commission employed "chloride of lime" for deodorizing the sewage of London, is reviewed. It is estimated that at the present time 90,000,000 people in 6,000 communities are drinking chlorinated water.—*R. E. Thompson (Courtesy Chem. Abst.).*

Three Water Districts Proposed for New Jersey. Eng. News-Rec., 104: 458–9, March 13, 1930. Three water districts, a $7,000,000 revolving fund with which the state would acquire reservoir sites and water rights for sale to the districts, and tentative plans for a high-level supply for the North Metropolitan District are the principal recommendations made by the New Jersey Water Policy Commission in Special Report No. 1, submitted to the Legislature on March 4. The fundamental principles laid down in the report are: joint ownership and pooling of all major sources of supply for each district, with interconnection of the various sources and pressure zones where topography of the areas served demands; divorcing of the ownership of joint sources from the distribution systems, the latter to be under municipal ownership; and sale of water at cost to the several municipalities by the central agency, with resale by each municipality "to its own inhabitants at rates consistent with good business and municipal practice." As constitutional limitations are held to prevent state financing of water districts, some other scheme must be devised, possibly through "an outgrowth of the regional plan suggested" now under consideration in New Jersey. Brief details are given of the proposed limits, supply sources, etc., of the Northern Metropolitan District, which is now served by 34 systems.—*R. E. Thompson.*

Integral Method of Waterproofing Concrete. Howard I. Seney. Cont. Rec. and Eng. Rev., 44: 349–50, 1930. Brief discussion of various theories of waterproofing concrete. It has been demonstrated in the laboratory that concrete, even with 1:3:5 mix, can be made absolutely waterproof without use of a waterproofing compound, but it is difficult to secure such results in the field.—*R. E. Thompson.*

Studies of Pipe Joints and Pipe Coatings. Eng. News-Rec., 104: 718–9, May 1, 1930. Condensed summary of papers and discussions at American Gas Association meeting held in April. K. R. Knapp described research work at American Gas Association testing laboratory at Cleveland. To date, study has been confined to pipes of small size, mostly 4-inch, and bell-and-spigot joints. About 30 specimens of old joints were obtained, ranging up to 50 years in age. In general it was found that old cement joints tested required application of a higher load to produce leakage than did old lead joints. Load which produced maximum deflection was also much higher with cement joints. Leakage tests upon remade joints gave uniformly unsatisfactory results. Use of leak clamps showed much greater possibilities than any other method of repair yet tried. Research work on new joints has consisted chiefly in determination of effects produced in bell-and-spigot joints by expansion caused by seasonal temperature changes. It appears that the principal strength of cement joints lies in the bond between cement and pipe metal: it is impossible to develop the shearing strength of the jointing material. Tests of lead joints indicated that a very important factor in causing failure under these conditions is roughness of the surface of the castings, causing scoring of the lead during longitudinal movement. Results with machined specimens suggested the desirability of using smooth surfaces. Methods of testing are described. In a description of pipe joint research conducted at laboratory of United Gas Improvement Co., H. W. Battin pointed out that these tests paralleled the expansion and contraction tests of American Gas Association. Tests bear out findings of the Cleveland laboratory that cement joints, whether neat or with mixtures of sand, are dependable only for ordinary low-pressure distribution. It was suggested that most frequent cause of joint failures in gas mains is unsatisfactory condition of foundations, allowing greater settlement at spigot end of each length than at bell end, where support can be carefully prepared. Settling of the spigot end in bell of the adjoining length causes compression of the lead in the bottom of joint and an open space at the top. Careful records indicate that 75 percent of failures occur at the top of the joint. Experiments recently conducted by a manufacturer indicate that effect of temperature changes on integrity of joints is not nearly so important as effect of vertical or lateral ground movement. Studies are being made at Bureau of Standards of soil action on pipe coatings. It has been learned that settling of the backfill over the pipe and its subsequent shrinkage, especially with change in moisture content, together with forces of adhesion between soil and coating, can cause distortion and disruption of bituminous coatings. A group of pipe lines, totalling 32 miles, in southeastern Great Lakes district has been selected for study. Some of these lines have been in service over 40 years. Examination of records of line replacements in conjunction with study of chemical characteristics of

soil at various points indicates close relationship between soil corrosiveness and soil acidity.—*R. E. Thompson.*

Collapsed Alexander Dam a Notable Structure. Eng. News-Rec., **104**: 703, April 24, 1930. Alexander dam on the Island of Kauai, Hawaii, which collapsed on March 26, was a hydraulic-fill structure being built by the McBryde Sugar Co. to impound water for irrigation. The type of dam was determined by the site, in a narrow inaccessible canyon. The height was to be 125 feet, crest length, 620 feet, maximum thickness at base, 640 feet, and total volume 580,000 cubic yards. The first unit to be constructed was a 1500-kilowatt power house, to operate the hydraulic giants for sluicing. Two 8 x 8-foot tunnels fed the forebay and diverted the stream during construction. Next unit was a hydraulic-fill pioneer dam 50 feet high, which was ultimately to form the upstream part of the heel of main dam. When pioneer dam was completed and sluicing commenced on main dam, seepage through the porous stratum of valley floor began to appear. A cutoff of alkali-treated fill with center wall of concrete resting on rock in trench dug through the porous stratum successfully stopped the seepage. Soda ash added amounted to from 40 to 50 pounds per ton of soil. Brief details of construction included. Because of favorable character of the fill, use of black powder to break it up, and maintenance of proper relationship between water pressure and volume, deposition in the dam fill averaged between 12 and 21 percent of water pumped.—*R. E. Thompson.*

Barming Service Reservoir Extension. Novel Method of Construction for the Maidstone, England Waterworks Co. Anon. Water and Water Engineering, **33**: 385, 5–9, January 20, 1931. In new method, called "reinforced steelwork," steel component of structure is initially erected in form of rigid, self-supporting and truly aligned skeleton, to which centering or mould for concrete is attached. Reservoir is covered and has capacity of about ¾ million gallons. All walls are constructed to horizontal and vertical planes of stoppage and V-grooves in constructional joints on water face side are pointed with elastic and adhesive bitumastic compound. Floor is structurally isolated from walls and is formed of two superimposed layers built in checkerboard fashion, the upper squares breaking joint with the lower. Roof is designed to carry four inches of gravel and four inches of soil plus superimposed live load.—*Arthur P. Miller.*

Water Mains. H. J. F. Gourley. Water and Water Engineering, **33**: 385, 9–11, January 20, 1931. Brief discussion of modern pipe materials, inluding iron cast vertically and centrifugally and welded and riveted steel. Consideration is given to merits of various pipe linings, such as those of cement mortar, or of bituminous nature; to protecting pipes against aggressive soils; and to various jointing materials. Concludes with short discussion of testing of completed mains before acceptance.—*Arthur P. Miller.*

Preparation of Engineering Schemes. Government Departments' Requirements. Anon. Water and Water Engineering, **33**: 385, 13–15, January 20, 1931. Discussion of provisions regarding finance, estimates, water supplies, sewerage and sewage disposal, and treatment of trade effluents. In connection

with water supplies, it is desirable to secure Ministry of Health's approval of proposed source as early as possible and before expenditures are made. In connection with trade effluents, writer's opinion is that a general standard for them would often create great hardship and would entail needless expenditure. Different standards for different rivers, or for different portions of the same river, should work more efficiently and economically.—*Arthur P. Miller*.

Ewden Valley, England, Waterworks. Anon. Water and Water Engineering, **33**: 383, 15–16, January 20, 1931. When water first impounded in Broomhead reservoir of this system, there was considerable leakage, which increased as head on upstream face of embankment increased, amounting in dry weather to over two million gallons per day. Boreholes were sunk to investigate underground conditions and then utilized for injection of cement into fissures. Loss was cut down in this way and after reservoir was emptied, further cementation work was done. It appears that the remedial work will be quite successful. Settlement cracks in masonry of adjacent works have also appeared; trial trenches have been dug and other exploratory work done to determine extent and causes of this slip and nature of remedial work necessary.—*Arthur P. Miller*.

Baddingsgill Reservoir: Lynn Scheme. New Water Scheme for the Bathgate District of West Lothian, Scotland. Anon. Water and Water Engineering, **33**: 385, 16–19, January 20, 1931. Scheme consists of reservoir from which 24-inch cast iron pipe carries water eighteen miles to one-million-gallon concrete service tank. Area draining into storage reservoir is well suited as source of water supply, being almost entirely rough moorland pasture and heather with very little peat. Dam is earthern embankment with puddle core rising to height of 84 feet. Upstream slope is protected by pitching of native stone on lower portion and by concrete blocks on upper portion. When full, reservoir has surface area of 61 acres and length of $\frac{3}{4}$ mile. Its greatest depth will be 78 feet and it will have storage capacity of 495 million gallons.—*Arthur P. Miller*.

The Value of Regular Systematic Examination of Water. J. M. Beattie. Med. Officer, 1930, **44**: 157–60. From Bulletin of Hygiene, **6**: 1, 73, January, 1931. To bring out value of regular bacteriological examinations of a water supply at short time intervals, writer describes system in vogue in Liverpool, England. Intervals between samplings are determined generally by results obtained. Frequent testing permits detection of fluctuations in bacterial counts, whether due to increased pollution, or otherwise. Thorough knowledge of fluctuations to which a supply is subject enables bacteriologist to detect departures from normal, if constant laboratory control is maintained.—*Arthur P. Miller*.

Lead Poisoning from Drinking Water in Leipzig. Kruse and M. Fischer. Deut. Med. Woch., 1930, **56**: 1814–18. From Bulletin of Hygiene, **6**: 1, 74, January 1931. From July to October, 1930, 250 cases of lead poisoning occurred among a population of 700,000 in Leipzig, Germany. Actual number of cases was greater, for blood examinations of further 2,000 individuals revealed

signs of lead poisoning in about one-third of them. Only those who lived in houses erected within the last two or three years were exposed to the lead poisoning, but, aside from this fact, explanation of outbreak is obscure. Part of water supply has been taken, since second quarter of 1929, from a new source; but analysis does not reveal any difference between new and old supply which would account for larger amounts of lead found in 1930. Suitable warnings were given the public against using water which had been standing for any length of time in the pipes and to flush out adequately before collecting for use. Those believing themselves affected were given free medical examination. Treatment of supply with lime water before distribution reduced plumbo-solvent power.—*Arthur P. Miller.*

Effect of Citrus limonia Osbeck (Imported American Lemon), C. aurantifolia (Christm.) Swingle (Dayap), and C. mitis Blanco (Calamansi) in Water Treatment. R. MACASAET and A. P. DERODA. J. Philippine Is. M. Assoc., 1930, **10**: 223–32. From Bulletin of Hygiene, **6**: 1, 74, January, 1931. Germicidal effect of juice of three species of citrus was tested on polluted shallow well water and on several bacterial suspensions in sterile water. Of species examined, cholera vibrio seemed to be most susceptible to action of juice, although typhoid and dysentery were also destroyed: *B. coli* displayed considerable resistance.—*Arthur P. Miller.*

River Pollution and Fisheries. A non-technical Report on the Work during 1926, 1927, and 1928 of the Standing Committee on River Pollution appointed in 1921. Ministry of Agriculture and Fisheries Standing Committee on River Pollution. H. G. MAURICE. From Bulletin of Hygiene, **6**: 1, 74–75, January, 1931. Tasks entrusted to this committee included evolvement of suitable provisions as to pollution in Salmon and Freshwater Fisheries Bill and securing the effective working of these provisions; collecting scientific information as to purity of rivers; and assisting in discovery of remedial measures. History of movement to alleviate river pollution is touched upon and results of some of the scientific investigations are given in the appendices. Tremendous volume of effluent from beet sugar factories is best handled by using waste water over and over again, so that final quantity needing disposal becomes small. This is discharged over the land from which it is drained into river without causing complaints. Experiments to ascertain toxic effects of aqueous extracts of tar on fish showed that yearling trout were very susceptible to tar washings, 2 parts per 100,000 proving lethal in less than an hour. It was found that resistance of the fish to tar decreased with age. In still another appendix there is a classification of rivers of England and Wales as regards their degree of pollution.—*Arthur P. Miller.*

Studies of the Antiseptic Action of Thiocyanates. I. Communication. The Disinfectant Action of Thiocyanic Acid and of Sodium Thiocyanate in Neutral and in Acid Solution. G. LOCKEMANN and W. ULRICH. Ztschr. f. Hyg. u. Infektionskr., 1930, **111**: 387–419. From Bulletin of Hygiene, **6**: 79, January, 1931. N_1 (sodium fluoride) and N_4 (sodium chloride) are without antiseptic action on *B. coli* and other bacteria in 48 hours. Sodium bromide has an

action, but not as strong as sodium iodide, while sodium thiocyanate is stronger than either. Free thiocyanic acid is extremely active, being between four and sixteen times as active as hydrochloric acid against *B. coli*. Thiocyanic acid is approached in activity by trichloroacetic acid. This degree of disinfectant action is regarded as due to a reciprocal catalytic influence of thiocyanate ions and hydrogen ions.—*Arthur P. Miller.*

The Handling of Drill Rope in Well Construction. Anon. Johnson National Drillers Journal, May, 1931. Most fishing jobs can be traced back to carelessness in details. Material economies may be accomplished by protecting drive belts from the elements, oiling wire rope, keeping cable in good order on the drums, keeping the tool joints clean, etc. Drilling cable should be the right size. Too small a size results in short life; too large a size gives little advantage in life and makes drilling sluggish. A wire drilling line used without any provision for shock-absorbing will produce a severe shock on a regular manila line machine. Modern wire-line machines with shock-absorbing devices are proving successful.—*H. E. Babbitt.*

The Olean City Epidemic of Typhoid Fever in 1928. A. S. Dean. American Journal of Public Health, 21: 4, 390, April, 1931. Epidemic of 248 cases in fall of 1928 was due to break in submerged suction line from well in Allegheny River and insufficient chlorination of water supplied to city. There were 25 deaths, giving 10.1 percent fatality rate. Estimated population was 21,559 in 1928. City water was used by all persons affected and there was no other factor common to a significant proportion of the cases. There were over 1,000 cases of gastroenteritis in January and February, 1928, and over 5,000 during the latter half of August and the first half of September, prior to the onset of the typhoid fever. The water supply was derived from two sources; Olean Creek water, which was filtered, chlorinated, and pumped into the distribution system and South Olean well supply which came from 12 or more 6-inch and 8-inch tubular wells sunk in the low ground on the north side of the river. Water from the wells passed through screw-joint iron suction pipes across the river bed to the collection and suction well. After chlorination, instituted by a device which operated by remote control when the electric pump was started, the water was forced into the distribution system. Raw sewage from nearly half of the city entered the river above the wells. The City has issued bonds to the amount of $425,000 to settle claims. The average cost per person who had typhoid fever and lived will be about $1,550. The range has been from nothing to $16,556. It is estimated that the direct loss to Olean business because of the epidemic was $200,000. The enlargement and improvement of the water works since the epidemic have cost approximately $125,000.—*H. E. Babbitt.*

History of the Water Supply of Rockford, Illinois. D. W. Mead. Journal Assoc. State Eng'g. Societies, 6: 2, 97, April, 1931. In the early 70's only the larger cities of the United States had installed public water supply systems. There were no engineers who were offering their services to the public along water works lines. City councils and their committees felt quite able to cope with the needs of their communities with such gratuitous advice as was offered

by interested manufacturers. The article then proceeds to give detailed history of the development of the city water works.—*H. E. Babbitt.*

The Value of Clean, Soft Water. C. H. Koyl. Journal Assoc. State Eng'g. Societies, 6: 2, 107, April, 1931. Railroads are always glad to purchase municipal water if quality and price are suitable, but henceforth such water must be soft. The coal bill for an ordinary locomotive in an average year is $12,000. One hard water might increase this bill by 10 percent. Local boilers are in the same position as railroad boilers. For a 100-horse power boiler, operating 24 hours per day, saving from using soft water as against water 12 grains per gallon hardness amounts to $700 per year. If we assume price of soap to be 12 cents per pound, then cost of excess soap to soften Rockford, Illinois, City water is $18.36 per family per year, or a total cost of $312,120 per year. At the last report 134 municipalities in the United States had installed water softening plants, because it pays for every family in town and because it contributes to the growth of the town.—*H. E. Babbitt.*

Court Decisions Relating to Public Health. Death Resulting from Drinking Impure Water Held Death by Accident Under Workmen's Compensation Act. Public Health Reports, **46**: 19, 1116, May 8, 1931. (Indiana Appellate Court; State et al. *v.* Smith, 175 N. E. 146; decided Mar. 4, 1931.) Employee of State highway commission became ill with gastroenteritis from drinking polluted water furnished to him while at work. Later, pericarditis developed and death ensued. In proceeding by employee's widow under workmen's compensation act, appellate court affirmed industrial board's award of compensation, holding that death was one by accident within meaning of compensation law. **Order of State Board of Purification of Waters Sustained.** Ibid., **46**: 20, 1192–1193, May 15, 1931. (Rhode Island Supreme Court; Board of Purification of Waters *v.* Town of Bristol, 153 A. 879; decided Mar. 18, 1931.) State board of purification of waters found that pollution caused by discharge of sewage by town of Bristol into waters of Bristol Harbor constituted menace to public health. Board ordered town to prevent such pollution and to submit to board plan describing system which town proposed to adopt. Town appealed on ground that order was unlawful, claiming that board had no authority to regulate, or prohibit, discharge of sewage by town into public waters of State. Order of board was sustained.—*R. E. Noble.*

Swimming Pool Sanitation. Frank R. Shaw. Municipal Sanitation, 2: 6, 276, June, 1931. Author traces development and numbers of public swimming pools since 1880. Regarding developments in purification, re-circulation was first used at Pawtucket, R. I., in 1906. First swimming pool standards were those of American Association for Hygiene and Baths, 1915. First application of chlorine was from a chloro-boat at Washington, D. C., bathing beaches in 1922. Serious thought is now being given to subject of natural bathing places and much excellent research and correctional work is under way. General trend is toward standardization. That of construction has been toward larger pools. In treatment of pool water, re-circulation system is best, as it makes possible more definite control of sanitation. Practice is toward in-

creased filter area, more rapid filter wash, and more frequent filtration. Need is emphasized for use of chemical receiving chambers and definitely controlled chemical feed machines ahead of filters. Trend in sterilizing is toward use of chlorine in sufficient excess to give a fairly constant residual, adequate to take care of additional pollution introduced by each new bather. Merits of sodium hypochlorite and of chloramine (ammonia and chlorine) are now being extensively investigated. In operation, trend is to maintain pools pleasing to the eye, to make sufficiently frequent tests to insure sterilization, and to keep daily records on pumpage, periods of filtration, turbidity, alkalinity, hydrogen-ion concentration, temperature, residual chlorine, and pounds of chemical used. A problem not easily mastered is that of foot diseases. Control is being established, however, by elimination of canvas mats, avoidance of wood walkways, periodic sterilization with chlorinated lime, or with chlorinated soda, of all surfaces coming in contact with the feet, and compulsory shower bath before entrance to pool. To benefit from continued and increased public interest, pool owners and operators should provide pools adequately controlled and operated. Complete and accurate records must be kept regarding operation and data provided which will refute claims or allegations about contraction of infections in pools.—*R. E. Noble.*

The Law of Easements. LEO T. PARKER. Municipal Sanitation, 2: 6, 284, June 1931. An easement is a right acquired by a property owner from long and continuous usage without objection on the part of other owners of adjacent property. A property owner is entitled to the free and exclusive enjoyment of all water courses, not navigable, which flow over his land. Diverting, obstructing, or adulterating the stream, so as to inferfere with its value to him, is a legal trespass upon his property. The mere fact that a property owner remains inactive and offers no objection, when knowing that owner of adjoining property is constructing a drain, does not in any sense indicate permission to utilize drain. MCNABB *v.* HOUSER, 156 S. E. 595. An important point of the law is that neither a municipality, nor a private individual, may automatically acquire an easement. It must be proved that the property owner has in some manner promised such right or performed acts equivalent to his consent. Chicago, M. St. P. & P. R. Co. *v.* CROSS, 234 N.W. 569.—*R. E. Noble.*

An Epidemiological Study of Typhoid Fever in Six Ohio River Cities. M. V. VELDEE. Public Health Reports, 46: 25, 1460–1486, June 19, 1931. The prime object of sanitary regulation and control of a public water supply is practical elimination of all water-borne diseases, particularly typhoid fever. Purpose of this study was to investigate carefully each current case of typhoid fever occurring over a considerable period of time and examine its possible relationship to any recorded deterioration in bacteriological quality of public drinking water. Cities studied include East Liverpool, Steubenville, Ironton, and Portsmouth, Ohio; Wheeling, W. Va., and Ashland, Ky. Summarizing: (1) The Ohio River is the source of the public water supply for each city. Originally this was supplied to the public without treatment, but at time of this report all six supplies are treated by coagulation-sedimentation-filtration and disinfection with chlorine. Prior to installation of effective

treatment the public drinking water had an excessively high *B. coli* index during each month of the year. For the period 1926, 1927, and 1928, following purification, the *B. coli* index of the Portsmouth supply was less than 2 per 100 cc. for 98.1 percent of the days; of Ironton, for 96.7 percent of Ashland for 99.9 percent; of Wheeling, for 93.6 percent; of Steubenville, for 92.1 percent; and of East Liverpool, for 76.8 percent. The Portsmouth, Ironton, and Ashland supplies never exceeded an index of 2 per 100 cc. Wheeling exceeded this index on 1.0 percent of the days, Steubenville, on 2.9 percent, and East Liverpool, on 14.4 percent. (2) During the period of raw water consumption the typhoid fever incidence in each city was uniformly very high in every month of the year, a seasonal distribution which is typical of endemic water-borne typhoid fever. Following the installation of the present public water supplies, the typhoid incidence promptly fell to a low rate, comparable with those prevailing in other cities on the Ohio River watershed which have had safe water supplies since 1914. At same time, seasonal distribution changed to that of a definitely summer and fall disease. (3) A detailed epidemiological study of the cases of typhoid fever reported in these six cities during 1927 and 1928 failed to reveal any evidence, direct or presumptive, which implicated the public water supply as a vehicle for the transmission of the disease. Ample evidence did indicate that other modes of transmission were the route of contact. Twelve tables and 1 graph are included. The history of the public water supplies of the six cities is presented in abstract form with tables, as an appendix.—*R. E. Noble.*

How the Great Drought Has Affected West Virginia Water Supplies. E. S. Tisdale. Quarterly Bulletin, W. Va. State Dept. of Health, 17: 4, 3, October 1930. Rainfall was less than 50 percent of normal for West Virginia, and the drought brought a decided increase in typhoid. Cities which are supplying water by the flat-rate method should take immediate steps to meter their supplies. Parkersburg, through a waste-water survey, has stopped wastage of nearly 0.5 m.g.d. in a consumption of 3 m.g.d. Clarksburg and Bluefield have demonstrated the value of good engineering and farsighted planning for preventing water shortages.—*G. C. Houser.*

Sanitary Requirements for Producing Bottled Waters. J. B. Harrington. Quarterly Bulletin, W. Va. State Dept. of Health, 17: 4, 11, October, 1930. Public water supplies in cities of West Virginia are closely supervised. Until the protracted drought of 1930 appeared there was little supervision of bottled water supplies sold throughout the state. Work of finding out nature, amount, and quality of bottled waters is now being carried forward. No company has a right to dispense bottled waters in West Virginia without permit signed by State Health Commissioner.—*G. C. Houser.*

Water Filtration and Health. A. H. Kegel. Chicago's Health, 24: 44, 226, November 4, 1930. Typhoid fever death rate in Chicago has declined from high point of 173.8 in 1891 to less than 1 at present. Several factors have been responsible for this decrease. The first factor, from standpoint of time, was the diversion of the city's sewage away from Lake Michigan. Second great factor was the chlorination of the water supply. Contamination of Lake

Michigan will probably be increased in 5 or 10 years, owing to reduction in diversion of water through the Drainage Canal. When filtration is employed, it will constitute the first line of defense against water-borne disease. Expense incidental to filtration is estimated at 2 cents per 1,000 gallons.—*G. C. Houser.*

The Work of the Sanitary Water Board. Part II. T. B. APPEL. Pennsylvania's Health, **8**: 6, 4, November-December, 1930. During 1929, 107 applications were received seeking approval of sewerage projects; and during same time were issued 85 permits covering such work. Progress has been made in carrying out the plan for treatment of Philadelphia sewage. This is important for protection of water supplies of Philadelphia and Chester. Trouble experienced by waterworks due to tastes and odors resulting from discharge of phenolic waste waters has passed from a serious matter to one of infrequent occurrence in Pa., due to the Board's efforts. Under a coöperative agreement, drainage from bituminous coal mines will be concentrated, or diverted, to confine pollution by mine water to the smallest practical mileage of streams, other tributary streams being restored to normal condition.—*G. C. Houser.*

Drought: Its Menace and Defeat. H. E. MOSES. Pennsylvania's Health, **8**: 6, 16, November-December, 1930. Pennsylvania was hard hit by prolonged dry spell of 1930. Streams dried up, wells and springs failed, and crops were seriously injured. In aggravated cases of water deficiency, use of water for industrial purposes was subordinated to domestic use, even necessitating temporary shut-downs in extreme cases. One instance occurred where a 2½-mile pipe line was laid on the ground to pump water to a filter plant to augment the supply. Here also wash water from filter plant was pumped back to sedimentation basin and waste condenser water was pumped directly into distribution system. In spite of emergency in the State, month of August showed lowest typhoid morbidity for several years past, excepting August, 1928, which represents lowest figure for that month since 1906.—*G. C. Houser.*

Sanitary Engineering News. Monthly Bulletin, Indiana State Board of Health, **33**: 12, 189, December, 1930.—Fort Wayne proposes to construct water filtration and softening works, at estimated cost of $2,500,000. When phenol recovery works now under contract at an East Chicago coke plant is placed in operation, phenolic waste entering Lake Michigan from Indiana will have been reduced to a negligible amount. On December 6 the Kokomo Water Co. placed in service its new 3-m.g.d. iron removal and filtration plant. The Ohio River and Great Lakes Boards of Engineers have appointed a joint committee to study a standard method of biochemical oxygen demand determination to be used by State Health Departments in Ohio River and Great Lakes drainage basins.—*G. C. Houser.*

Report on the Water Resources of Connecticut by State Water Commission 1930. The Commission adopted as its program an investigation of the general subject, with particular reference to what had been accomplished in other states. The Commission is convinced that Connecticut must adopt a policy looking toward the conservation of its water resources. At present time there

is no agency charged with such duty. Commission submits draft of an act which would provide such an agency, charged with ascertaining and conserving available water supplies for all purposes. New Commission would absorb the State Water Commission and the State Board of Civil Engineers.—*G. C. Houser*.

Conserving Public Health in West Virginia: the Sanitary Engineering Division. E. S. TISDALE. Quarterly Bulletin, W. Va. State Dept. of Health, **18**: 1, 8, January, 1931. Sanitary engineering division of W. Va. department of health was created in 1915 for purposes of safeguarding public water supplies and reducing typhoid death rate, estimated at nearly 40 per 100,000 in 1915. Typhoid death rate in 1928 was 10.8 and in 1929, 11.4. The 63 water filtration plants in the state, which purify daily over 50 m.g. of drinking water, are under constant supervision by state sanitary engineers. The 1929 legislature enacted the State Water Commission bill, under provisions of which streams grossly polluted by sewage and industrial wastes have been studied and considerable remedial work has been done.—*G. C. Houser*.

Interpretation of Results of Water Examinations. C. C. CARSON. Connecticut Health Bulletin, **45**: 2, 47, February, 1931. Although inferences drawn from a sanitary analysis are based mostly on circumstantial evidence, they are usually on the safe side and tend to condemn water which is safe rather than to classify as satisfactory water which may be unsafe. Laboratory results only furnish information regarding past or present conditions; they are not a guarantee of future safety.—*G. C. Houser*.

Shall Illinois Have Sanitation and Conservation of Its Streams? H. F. FERGUSON. Illinois Health Quarterly, **3**: 1, 44, January-March, 1931. The last legislature passed a law creating Sanitary Water Board. Activities of board include review of plans for sewerage systems and advice in operation of sewage treatment works. A mobile water and sewage laboratory has been made available for carrying on work of board. At present there are 509 public water supplies in Illinois, of which 101 are obtained from surface waters. These surface supplies serve nearly 60 per cent of the population of Illinois. Sewage from only 30 per cent of population receives complete treatment before discharge into streams.—*G. C. Houser*.

Water Analysis and Water Supply. J. W. KELLOGG. Health Bulletin (North Carolina State Board of Health), **46**: 3, 8, March, 1931.—Sanitary analyses of water samples have been made in State Laboratory of Hygiene since 1908, and during that time nearly 90,000 samples have been examined, over 60 per cent of which have come from public water supplies of the State. There are at present about 230 public and semi-public water supplies, 90 of which are derived from wells and 140 from streams and surface water. Under State law samples from public supplies must be sent for analysis each month.—*G. C. Houser*.

Properties of Sewage Colloids. E. C. C. BALY. Trans. Faraday Soc., **27**: 5, 193–201, 1931; cf. C. A., **25**: 2220. Iso-electric point of sewage colloids was

found to be at pH 4.6, using fresh, diluted (1:15) material as basis of study. Presence of two types of colloids was shown by cataphoresis test; positive organic colloids and negative bacterial colloidal complexes. Addition of dilute electrolytes changed the iso-electric point: 0.15 per cent NaCl, to pH 6.5, and 3 per cent NaCl, to pH 8.3. Behavior of gelatine is similar, suggesting relationship of these colloids to proteins. The positive sewage colloids were flocculated by suspension of bentonite. These results suggest a system of free positive colloids together with negative bacterial colloidal particles in fresh sewage. Precipitation of these colloids was not obtained after 7 days of standing [possibly because sewage became septic—ABSTR.]. Bacterial increase was obtained upon suspending in 3 per cent NaCl solution. These colloids were easily flocculated by positive ions.—*Edward S. Hopkins.*

Shrinkage of Concrete in Actual Structures. WILLIAM M. BASSETT. Journal Boston Society of Civil Engineers, 18: 3, 67, March 1931. Laboratory studies of concrete indicate that shrinkage is due to (1) loss of free moisture by chemical combination, or by evaporation, and (2) loss of internal heat. Maximum longitudinal shrinkage amounts to about 0.055 percent. Author describes planning and construction of spillway and intake structures of Fifteen Mile Falls dam. Of eight 45-foot sections of spillway dam, which are of uniform cross section throughout each length, two are still without intermediate cracks; six have acquired them. Of ten 32-foot sections, four have acquired cracks; six are without them. The intermediate cracks start from the ledge and disappear before they reach the top. The twenty-three bulkhead joints have openings at the top amounting to 0.016 percent, as against the theoretical 0.055 percent, shrinkage. Spillway channel slabs, each 19 feet in length, have center reinforcing system of 0.5 percent and should develop ultimate shrinkage of 0.12 inch per slab length. There is a crack between each slab and its rib, varying in width from a hair line to about $\frac{1}{16}$ inch.—*J. F. Pierce.*

Simplified Rain-Intensity Formulas. C. E. GRUNSKY. U. S. Monthly Weather Review, 58: 10, October, 1930. Author suggests two formulas for determining mean intensity, I, in inches per hour, of rainfall whose duration, t, in hours, is known:

(1) $I = \dfrac{C}{\sqrt{t}}$ when t is less than 64, and

(2) $I = \dfrac{2C}{t^{\frac{2}{3}}}$ when t is 64, or greater.

C represents a coefficient which is to be ascertained for any locality from records of rainfall of extreme intensity. Total rainfall, R, during t hours of its duration, will then be given by

(1) $R = C\sqrt{t}$ when t is less than 64, or

(2) $R = 2C\sqrt[3]{t}$ when t is 64, or greater.

Value of C will be equal to maximum rainfall in one hour when $t = 1$.—*J. F. Pierce.*

Report of the Steam-Flow Prediction Subcommittee. A. STREIFF. U. S. Monthly Weather Review, 59: 2, February 1931. Author states that stream flow records never repeat themselves; ceaseless fluctuations exist, continually ranging between high and low levels, often apparently in recognizably systematic sequances. Great Lakes region appears to be distinguished by singularly regular sequence of stream flow. Cycle has faithfully recurred ten times since 1875. At present a minimum is approached, which will occur in 1931. A maximum will occur in 1935 and a high maximum in 1940.—*J. F. Pierce.*

Athens to Relieve Its Thirst. W. P. CHRISTIE. The American City, 44: 1, 95–97, January, 1931. In 1922, daily per capita supply of water for Athens, Greece, was only 1½ gallons. With arrival of Greek refugees from Turkey and other factors almost tripling the population within two years, water shortage became acute. By developing to the utmost all existing sources, available supply was raised to three gallons per capita. Later, water from construction tunnel doubled this supply. New system will render available from 16 to 18 gallons per capita, which will compare favorably with other Levantine cities. System includes dam impounding two rivers, delivery tunnel, and pipe lines and reservoirs for distribution. Dam, near field of Marathon, is of concrete, with facing of dressed marble. Architectural perfection has been striven for. Height above old stream bed is 180 feet and crest and spillway are 1200 feet long. Main delivery line to city includes 8½-mile tunnel of 7½ by 7½ feet horseshoe-shaped section, besides shorter tunnels, and cast iron syphon line 5½ miles long. It discharges into central reservoir from which water is distributed into 8 smaller reservoirs. Project will cost $13,000,000. Half of $10,000,000 development bond issue was taken up by contractor and half, by Bank of Athens. Design, construction, and operation of system during 20-year lifetime of bonds were coordinated under three-way agreement between these two agencies and Greek government, only latter having power to terminate the agreement.—*Arthur P. Miller.*

Modern Railway Sanitation. ISADOR W. MENDELSOHN. Municipal Sanitation, 2: 7, 322, July 1931. ((1) *The Development of Railway Sanitation.* First regular passenger conveyance, one hundred years ago, was open box mounted on wheels. Almost at once, railroads contributed to spread disease, for, the individual being the great source of infection, his transportation in the communicable stage has conveyed from state to state many infections. Railroad-borne epidemics of 19th century led to extreme and, often, unreasonable railroad quarantines, rigidly enforced until toned down by enlightenment and economic pressure. Much hardship was experienced therefrom by passengers. First Interstate Quarantine Regulations were promulgated September 27, 1894. First state regulation of railway sanitation was by Texas, Minnesota, and Kentucky, 1904–1906, and pertained chiefly to fumigation, then regarded as panacea against all infectious disease. For ten years, state regulations displayed little co-operation, or uniformity. In 1912, Northwestern Sanitation Association was organized and draft of uniform regulations for northwestern states formulated, which was adopted in 1914. In 1916, Interstate Quarantine

Regulations included those governing interstate common carrier traffic to prevent spread of disease. In 1920, standard Railway Sanitary Code was approved by Conference of State and Provincial Health Authorities, and recommended to states for adoption. In 1921, Interstate Quarantine Regulations were revised to essential agreement with code. In 1922, Joint Committee on Drinking Water Supplies of American Railway Association was appointed to recommend improvements where necessary in handling of drinking water for railroad cars. This Committee was changed to Joint Committee on Railway Sanitation in 1928. Its functions include preparation of manual of standard practice for railroads in handling of drinking water and in other allied features of railway sanitation. Present Interstate Quarantine Regulations apply to prevention of spread of communicable diseases from one state to another. Persons afflicted with cholera, yellow fever, plague, or typhus, are prohibited from travel by interstate trains. These regulations are enforced through co-operative action between Surgeon General of U. S. Public Health Service and State Departments of Health through mutual notification, permits, and inspections. (2) *Sanitation of railway Cars. Water Supply.* Prior to twentieth century, streams and wells were frequently adopted as sources of supply. Streams were then subject to considerable pollution, receiving untreated sewage and other city wastes. Mississippi River was an outstanding example and was much favored as railroad supply. Well and spring development was then extremely insanitary. The few filtration plants existing before 1900 had not attained present-day efficiency and sterilization was unknown. First systematic supervision of drinking water used on railroads was by Minnesota State Board of Health in 1913. With promulgation of bacteriological standard for drinking water on interstate carriers by Secretary of Treasury, on October 21, 1914, this acknowledged procedure took the place of the widely varying laboratory methods then prevailing. For administration purposes, under Interstate Quarantine Regulations, country is divided by U. S. Public Health Service into six interstate sanitary districts with sanitary engineer in charge of each to assist State Health Departments where necessary. Remarkable progress has been made in sanitary supervision over railroad drinking water, in past ten years. Earliest passenger cars were not supplied with drinking water. Later, 1859, cars were provided with tin wash basins in small toilet rooms, with water from the tin cooler drinking faucet. Next came use of hand pump from tank located on floor of wash room. Drinking water was obtained from tin coolers. About 1876 overhead gravity water tanks were installed. Then in 1891 came air-pressure water supply system. Coolers with separate compartments for ice and water were being installed in 1912 and, by end of 1925, had become practically universal. To-day, passenger coach of latest design has either overhead tanks located at each end with protected filling pipes extending underneath the car in each corner, or an air-pressure water system with tank underneath and filling pipe extending to each side. The same water is supplied for all purposes, drinking, culinary, washing, and toilet flushing. Thus the passenger today finds in this railroad car the same water convenience as in his modern home.—*R. E. Noble.*

Essential Factors in Design of Swimming Pools. M. P. Hatcher. Municipal Sanitation, 2: 7, 347, July 1931. Credit for improvement of standards for swimming pool sanitation must be given Joint Committee on Bathing Places, representing American Public Health Association and Conference of State Sanitary Engineers. Proper control implies and requires proper design. Earth fills supporting walls or floors should be well rolled and compacted. Complete gravel and open tile underdrain system is generally required. Considerations governing shape of pool are: (1) economical construction, (2) maximum safety for patrons, (3) proper proportion of deep and of shallow water, (4) proper distribution and collection of circulating water, (5) adaptability for swimming races under standard conditions, water polo, and other aquatic sports. Advantages and disadvantages of oval, rectangular, and fan-shaped types are given. Size of pool must be determined by study of local conditions and of records of other pools similarly circumstanced. Drainage time should be from four to six hours. Bath house and pool walks should be on same level, if possible. If steps are required at any point, they should be so arranged, or protected by railings, that running approach is impossible. Walkways should be reasonably rough to prevent slipping and should drain away from pool. Generous parking space should be provided near bath house entrance. Overhead lighting is essential. Filtration is absolutely essential for economical operation and a sanitary pool. Withdrawal of circulating water over scum gutter is suggested. From filter, water is returned to pool at deepest available point. Gravity filters appear economical for larger pools. Filters cannot function properly without adequate facilities for chemical application and for coagulation. Solution feed is preferable to "alum pot." Small chemical feed machines, now available at reasonable cost, give promise of further improvement. Alkalinity may be maintained by application of soda ash by means of dry feed machines. Too often, this point is neglected. Smarting of the eyes, so generally attributed to chlorine, will not be experienced if pH is kept above from 7.2 to 7.4 and chlorine residual, below 0.5 p.p.m. Avoid cross-connections with municipal water supply.—*R. E. Noble.*

NEW BOOKS

Report of Bureau of Sanitary Engineering, Maryland State Department of Health, 1930. Abel Wolman. 19 pp. (Mimeographed.) Extensive activities of Bureau during 1930 are reviewed. Severe water shortages occurred and many streams showed marked increases in salinity due to drought. Rainfall deficiency in some areas of state was 25 inches. Many auxiliary supplies had to be developed. Typhoid death rate, 6.2 per 100,000, however, while somewhat higher than that of previous year (4.2, the lowest on record), was no greater than the average for the preceding 4 or 5 years. Studies of corrosion in distribution systems were continued, data obtained strengthening assumption that reduction in dissolved oxygen is indicative of active corrosion. It was further found that water adjusted to minimum aggressiveness to wrought and cast iron is invariably actively corrosive to the cheaper steel pipe, comprising many service lines and domestic plumbing systems. Experiments made in connection with supplementary supply for Annapolis showed $FeCl_3$ to be

slightly superior to alum for coagulation; but, owing to cost of former, chlorinated copperas was recommended. Ammonia was successfully employed at several plants for prevention of taste. At Baltimore, prechlorination, with NH_3 added at the same point in mixing basin, was successful, detention period before filtration being about 40 minutes. Residual Cl_2 content of 0.1 p.p.m. was maintained after filtration, post-chlorination thus being rendered unnecessary. For protection of concrete sewers, City of Baltimore has set pH value of 4.0 as minimum for industrial wastes to be discharged therein. At one plant, waste pickling liquors will be diluted with river water in large tanks equipped with special injectors for adequate mixing, and pH value will be controlled by automatic recorders. Completion of save-all system at paper plant discharging its waste into Upper Potomac River has reduced paper fiber waste from 2000 to 100 pounds per hour. Unusually heavy growths of *Elodea Canadensis* at head of Middle River caused objectionable odors when the large surface mats of the water began to decay. Exceedingly prolific growths of *Clathyrocystis* and *Coelosphaerium* occurred in Back River in vicinity of outfall of Baltimore sewage disposal plant, despite systematic application of $CuSO_4$. Treatment of plant effluent with lime to remove free and half-bound CO_2 appeared promising but experiments showed that dissolved organic matter and nitrates were converted by bacteria into CO_2 and other substances of food value to plankton, thus neutralizing effect of lime. Details are included of investigations conducted in field of industrial hygiene and of oyster surveys made, together with lists of improvements made in water and sewerage systems of various cities, towns, and state institutions.—*R. E. Thompson.*

Useful Information About Lead. Lead Industries Association, 420 Lexington Ave., New York, cloth bound, 104 pages, profusely illustrated, price $0.50 post paid. This book tells concisely the story of lead and its principal uses. Should be of interest to users of lead and its products. Short chapters are devoted to the major industries consuming lead and the part lead plays in them, as well as the history, mining, smelting and refining of the metal. The table of properties of lead is probably the most complete and up to date ever published, including mechanical, thermal, electrical, optical and other constants. The chapter on lead compounds describes the manufacture and use of the more important varieties and has appended a table of many others, their characteristics, manufacture and uses. Many corrosive chemicals handled in lead equipment are listed and typical formulae of important classes of alloys are given.